

GAMA Program

Groundwater Ambient Monitoring and Assessment

John Borkovich, PG

GAMA Program

State Water Resources Control Board



Meeting Overview

- Goals of Meeting
- GAMA Background and Mission of PAC
- Program Accomplishments 2001-2013
 - Overview SWRCB
 - USGS
 - LLNL
- GAMA Future Work Scope and Funding

Goals of Meeting:

Solicit PAC members' direct input and to reach a consensus on:

- Priority Basin Project scope of work modifications
- Discuss securing future funding source(s) before the end of 2013

GAMA Background

- Legislature's concern about groundwater quality
- Budget Act of 2000
- Water Code Section 10780
 - Groundwater Quality Monitoring Act of 2001 - (AB 599, Liu)
 - *PAC and ITF created in law*
 - Groundwater Quality Monitoring – (2008. AB 2222, Caballero)
 - Outlined funding needs for GAMA

GAMA PAC Mission

- AB 599 directed the State Water Board to convene an advisory committee (PAC) to develop the comprehensive ambient groundwater monitoring program elements.
- The PAC provides expert external advice and guidance to the GAMA program.
- The PAC was instrumental in securing funding for GAMA.

GAMA Program Objective

Is ambient groundwater quality in California getting better, worse, or staying the same?

➤ *The answers depend on:*

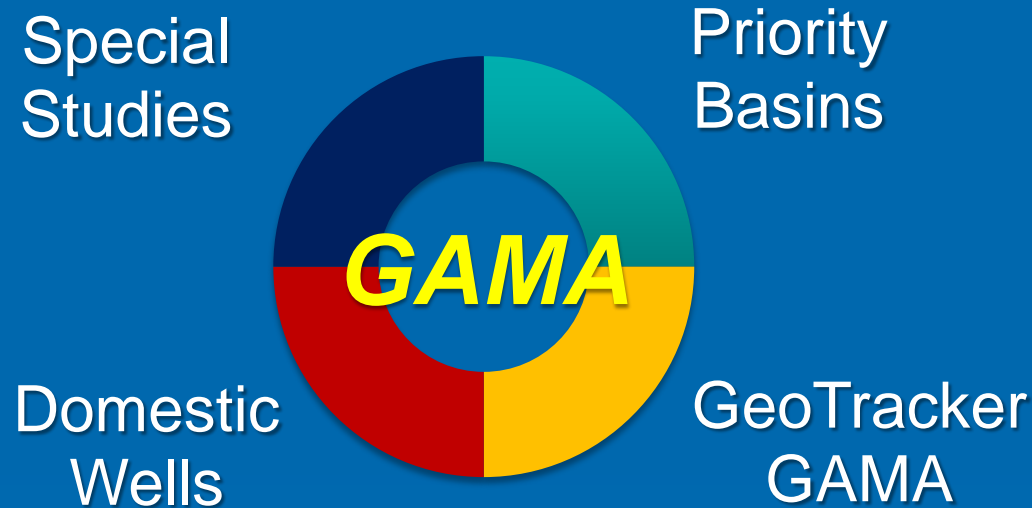
- Where, how, and how often you collect samples (new and shared data); collaborate with other studies
- What chemicals are you testing for and comparing it to what concentration or level; assess water quality
- Reporting, sharing data, staying focused on overall goal: comprehensive monitoring and sharing data with public

Ambient Groundwater Monitoring: *Importance*

- Establishes baseline groundwater quality on a basin wide scale
- Sampling repeated periodically to identify trends in water quality
- Data collected and analyzed to be used by decision makers to better protect groundwater resources; centralize data

GAMA Program Accomplishments

GAMA Program: Current Projects



Sampling conducted in *Voluntary Cooperation* with Participants

GeoTracker GAMA Groundwater Information System

- Provides to public data from CDPH, USGS, LLNL, DWR, DPR, and Water Boards
 - Water quality, water levels, contaminant sources, groundwater publications
- Internet accessible w/ Google map
- Search for >220 chemicals from all datasets for over 200,000 wells (>100 million results)

Fulfills AB599 intent of a centralized info system

Domestic Well Project

- 1,146 private wells sampled - six counties
- Key Results (2003 to 2011):
 - Total Coliform: 26% wells positive
 - Fecal 3.2%
 - Nitrate: 10% wells > MCL
 - *Nitrate: 41% of Tulare wells > MCL*
 - Radionuclides (gross alpha): 33% San Diego >MCL
 - Perchlorate: 6% > MCL
 - VOCs: less than 1% > MCL

Fulfills AB 599 intent to make water quality data more available to public - State Board Staff Technical Lead

Special Studies Project

- Focus on areas of groundwater concern (*occurrence, source*)
 - Wastewater, septics
 - Dairies
 - Nitrate
 - Recycled Water
- Investigative Tools
 - Age dating (H_3/He)
 - Isotopes (N, O, H, B)

Fulfills AB 599 intent to better understand groundwater quality - LLNL Technical Lead

Priority Basin Project

- Baseline assessment cycle complete: 95% of the state's public-supply aquifers characterized
- Project calls to repeat the public aquifer assessment every 10 years
- 2,400 wells sampled
- Dozens of reports, fact sheets published

Fulfills AB 599 intent to more comprehensively monitor groundwater quality - USGS Technical Lead with LLNL support

Priority Basins: *Future Funding*

- Priority Basins funding (Prop 50 bonds) to **cease** in 2015
- **New Funding Source Not Yet Identified**
- Reconvene PAC today to discuss potential options

Important Points/Findings:

- Most land uses can impact groundwater quality
 - Shallow groundwater more vulnerable to anthropogenic contaminants
 - Deeper water typically better quality, but has several contaminants-usually at lower concentrations than shallow
- Regularly monitoring groundwater quality is critical to track impacts over time

GAMA Program's Next Steps:

- Assess shallow aquifer quality
- Study groundwater quality trends (*shallow and deep*)
- Assess relationship between surface activities and groundwater quality
- Evaluate findings to help us better manage our groundwater resources



GAMA Program's Impact:

- GAMA Program is an invaluable resource for:
 - General public
 - Government agencies
 - Non-governmental organizations
 - Legislators
 - Scientists
 - Educators
- No other state has such a comprehensive program for groundwater



Thanks

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<http://geotracker.waterboards.ca.gov/gama>

GAMA Special Studies: Focused Water Quality Investigations of State Wide Relevance

**A Presentation to the
GAMA Public Advisory Committee
April 30, 2013**

**Bradley K. Esser
Lawrence Livermore National Laboratory**



LLNL-PRES-635766

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What is a GAMA Special Study?

- **A focused water-quality investigation**
 - Local to regional scale
 - Specific water quality issue
 - Limited duration study (for flexibility in addressing new concerns)
- **Of state-wide relevance**
 - Common or emerging water quality issue affecting groundwater used for drinking water
- **Using innovative & scientifically credible methods**
 - Development of new approaches and tools
 - Scientifically credible case studies using cutting-edge science
 - Publications in peer-reviewed literature
- **With outreach to the professional community & public**
 - Voluntary program
 - Work with local agencies, well owners & stakeholders
 - Involve & train students and agency staff

Goal: Science-Informed Policy

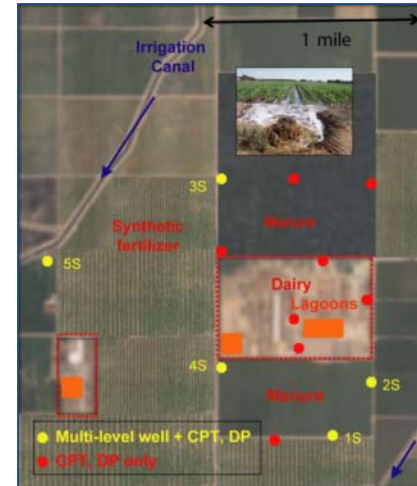
A Focused Water Quality Investigation



A single well

Is high nitrate in a city well from orchards or a farm supply yard?

Is high nitrate in a community well affected by agricultural nitrate?



Small dairy farm

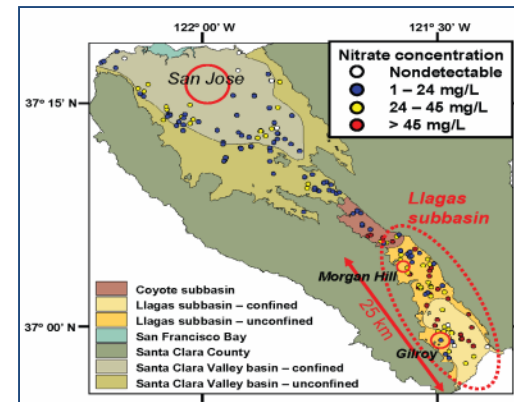
Transport & fate of dairy-derived nitrate to underlying aquifer



A managed aquifer recharge operation

How can we trace recharged water without SF6?

Is high arsenic caused by recent recharge operation?



Groundwater basin

Sources of nitrate and impact of nutrient management plans.

Impact of climate change on alpine headwater basins.

Using Innovative and Scientific Methods

Groundwater Age Dating

- Delineate groundwater recharge, flow & contaminant transport
- Proxy for aquifer susceptibility
- Tool for assessment of management practices and contaminant source attribution

Isotope & Dissolved Gas Geochemistry

- Water source (stable isotopes of water)
- Water “tagging” (introduced gas tracers)
- Contaminant source (isotopic composition)
- Contaminant degradation (e.g. denitrification)

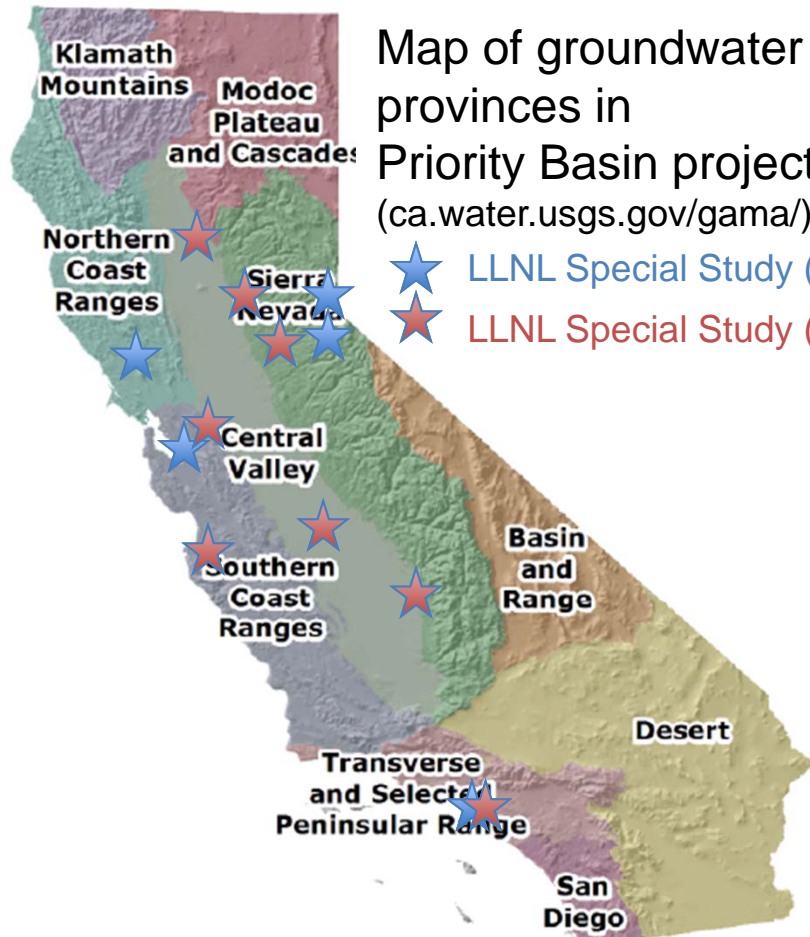
Industrial VOCs & Emerging Contaminants

- Proxy for aquifer susceptibility
- Contaminant source tracers
- Emerging contaminant transport & degradation in subsurface

Of State-Wide Relevance

- **Nitrate in groundwater – sources, fate and transport**
 - Nitrate impacts from point & non-point sources
 - Basins with nitrate management plans or MCL exceedences (e.g. Llagas & Salinas)
 - Central Valley dairies & Tulare County domestic wells
 - Municipal wells (e.g. Ripon)
 - Development & demonstration of nitrate source, fate & transport
 - Isotopic composition and co-contaminants
 - Quantification of denitrification
- **Wastewater impacts on groundwater**
 - Development of new tracers of wastewater in groundwater
 - Pharmaceuticals (carbamazepine); artificial sweeteners; and boron isotopes
 - Impact of septic discharge and recycled municipal wastewater
- **Groundwater recharge and transport**
 - Development of new age tracers for groundwater recharge
 - Introduced tracers (to replace SF6) and natural tracers
 - Water quality changes during groundwater recharge
 - Impact of climate change on recharge in headwater basins
 - Identification of recharge area and surface/groundwater interaction

Overview of GAMA Special Studies:



Map of groundwater provinces in
Priority Basin project
(ca.water.usgs.gov/gama/)

- ★ LLNL Special Study (Age)
- ★ LLNL Special Study (Nitrate)

Priority Basin program provides excellent state-wide monitoring of groundwater quality!

Special Studies supplement Priority Basin program in *Focused Investigations*

Groundwater age

- new age tracers for managed aquifer recharge
- groundwater recharge, sustainability & vulnerability to climate change

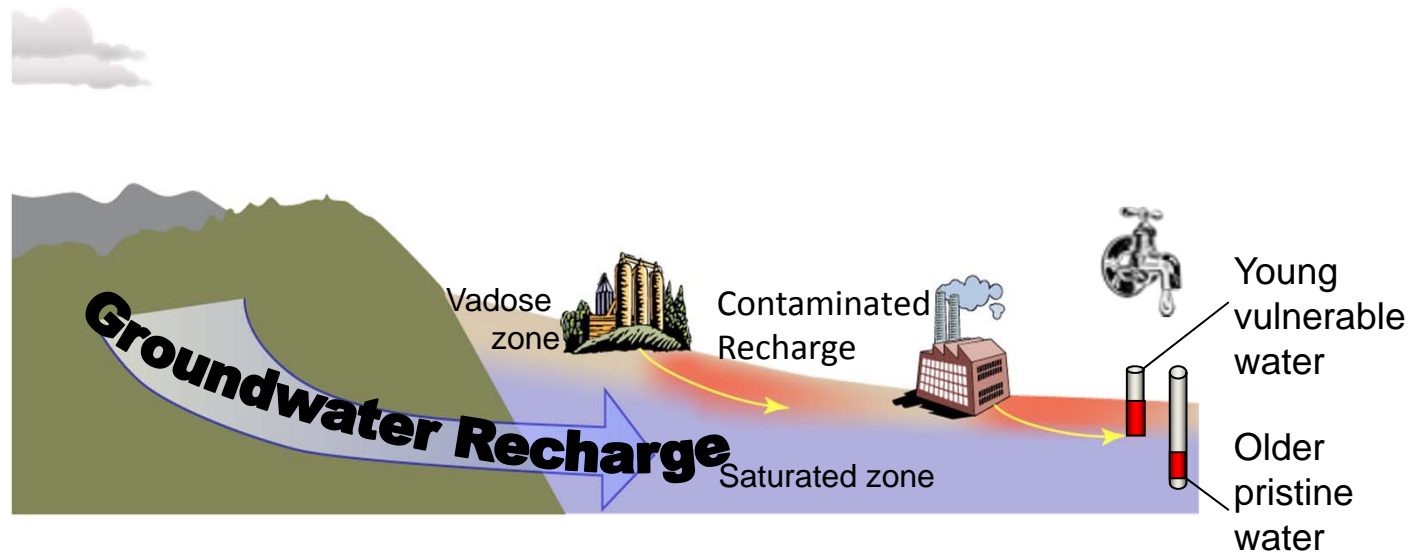
Multi-tracer studies of groundwater nitrate

- Isotopic approach to distinguish nitrate source and history
- Dairy impacts on Regional Aquifer

Leveraging age tracer data in the GAMA dataset

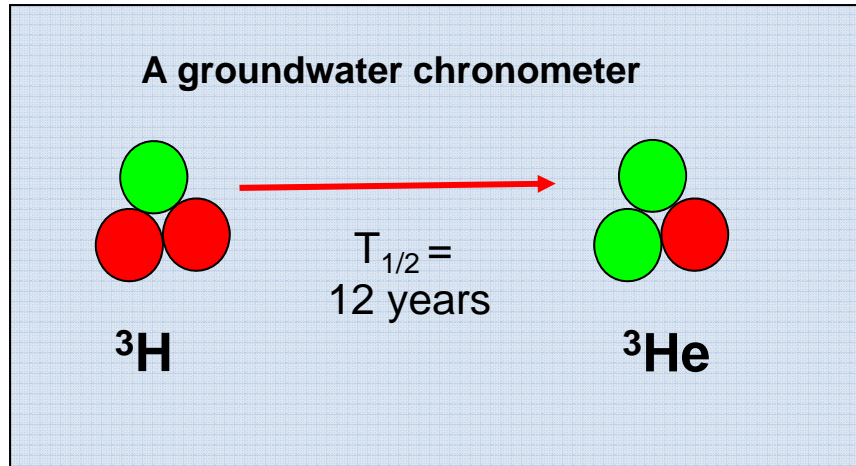
- “Pre-modern” water quality in ambient groundwater (state-wide)

Theme: Groundwater Age Tracers

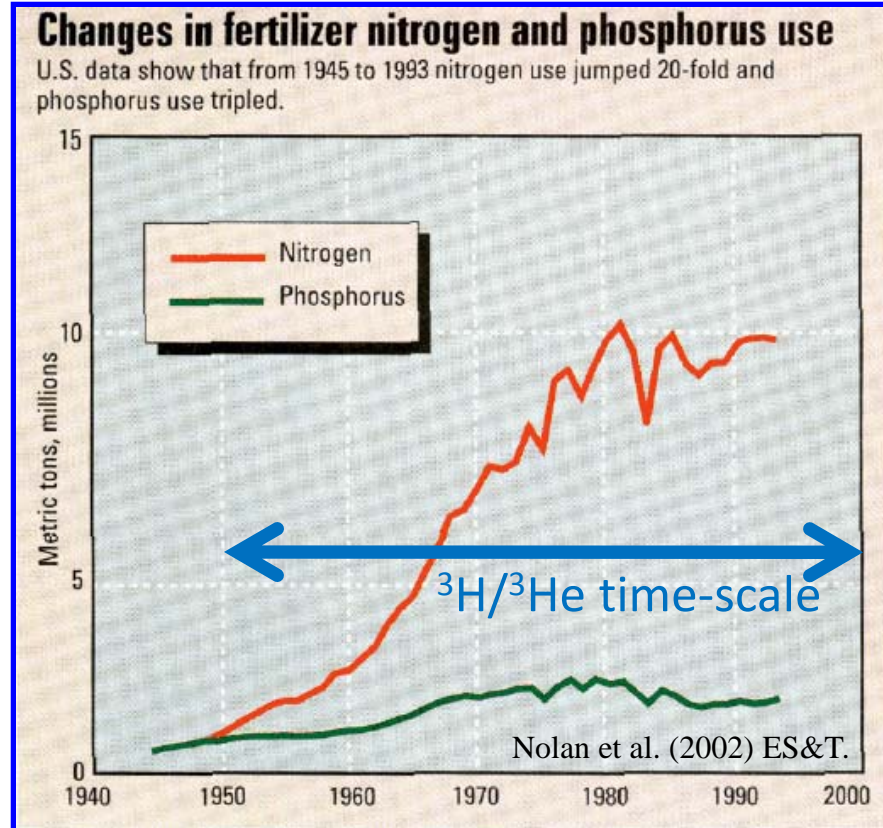


- **Aquifer susceptibility**
 - Recharge in last 50 years (during expansion of population, industry & agriculture)?
 - Recharge over long flow paths allowing for mitigation by mixing or degradation?
- **Contaminant attribution**
 - Is the contamination from legacy or current source?
 - Is the contamination from local or non-local sources?
- **Regulatory compliance: managed aquifer recharge of recycled water**
 - Meets retention time regulations for drinking water wells?

The tritium/helium ($^3\text{H}/^3\text{He}$) method measures groundwater age on an appropriate time-scale for water resource studies



- The method is useful over the last 50 years with an uncertainty of 1-2 years.
- The method also allows identification of mixing with very old groundwater in the produced water (through analysis of radiogenic He-4)



Most public-drinking water wells in California produce water with measurable tritium.

Groundwater age: Tritium alone is misleading

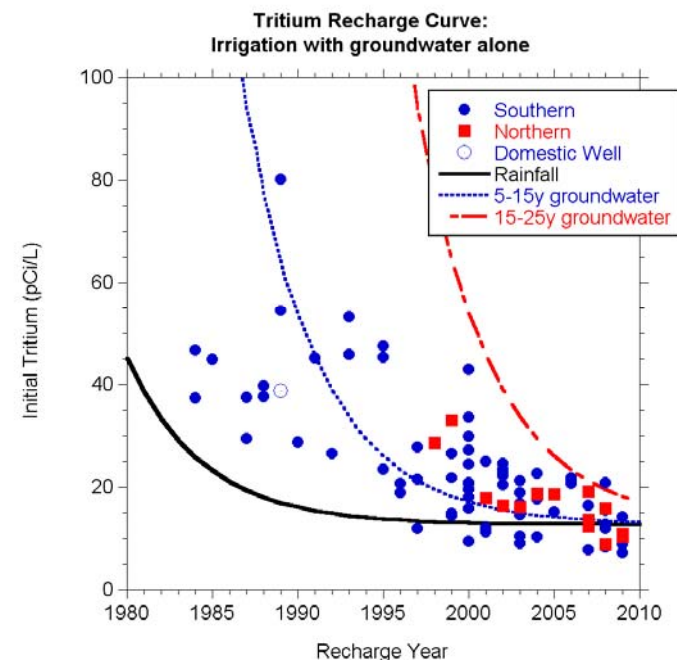
Tritium activity is affected by groundwater age and groundwater mixing *and recharge source*

Location	Tritium (pCi/L)	GW age (years)
Bakersfield	11.1	15
	11.3	34
San Jose	12.4	11
	12.5	42

Recharge from irrigation with pumped groundwater and groundwater mixing

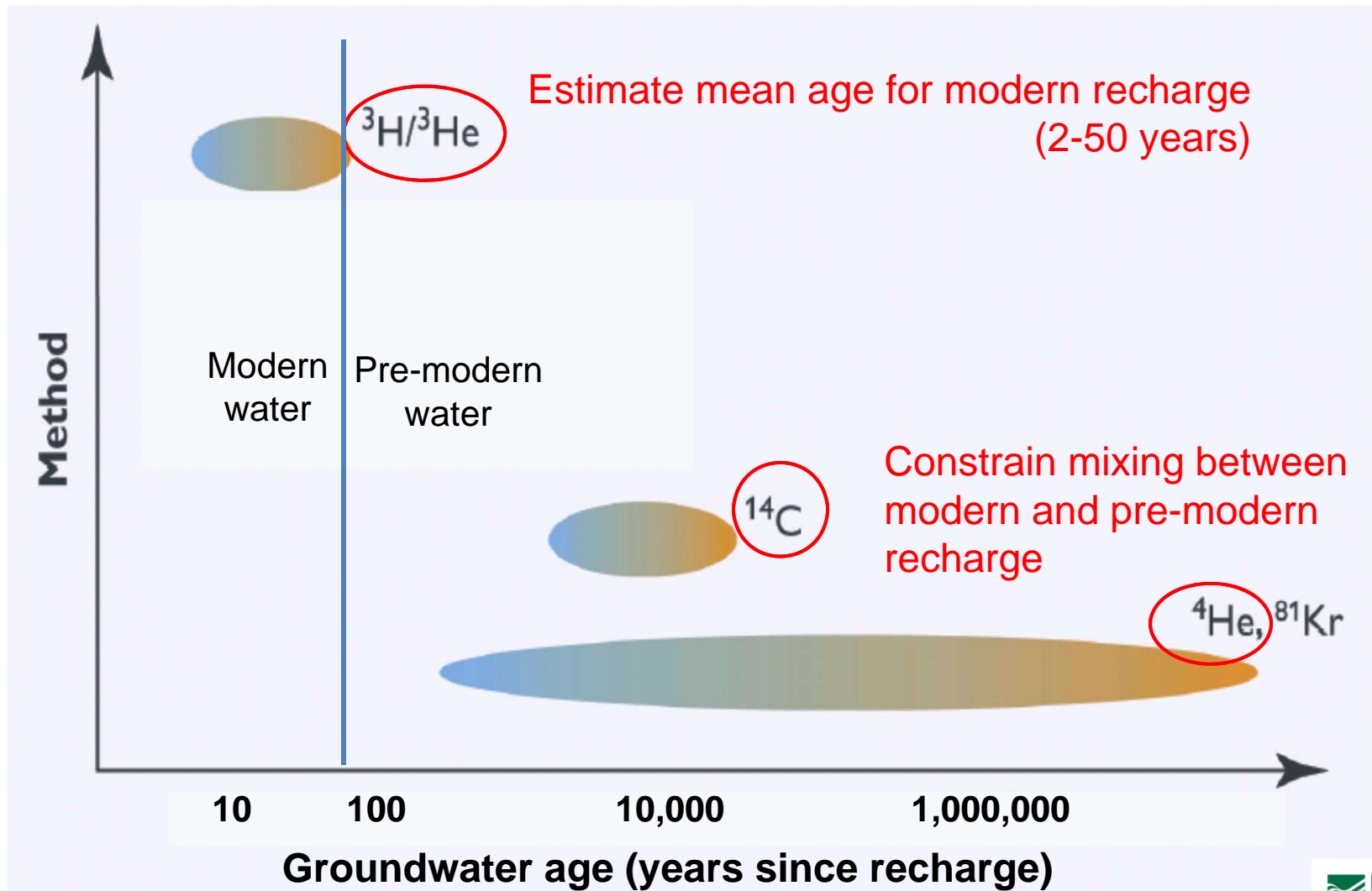
- **Will not affect** tritium-helium groundwater ages
- **Will affect** tritium-only model ages

A significant source of recharge in the Central Valley is irrigation with pumped groundwater

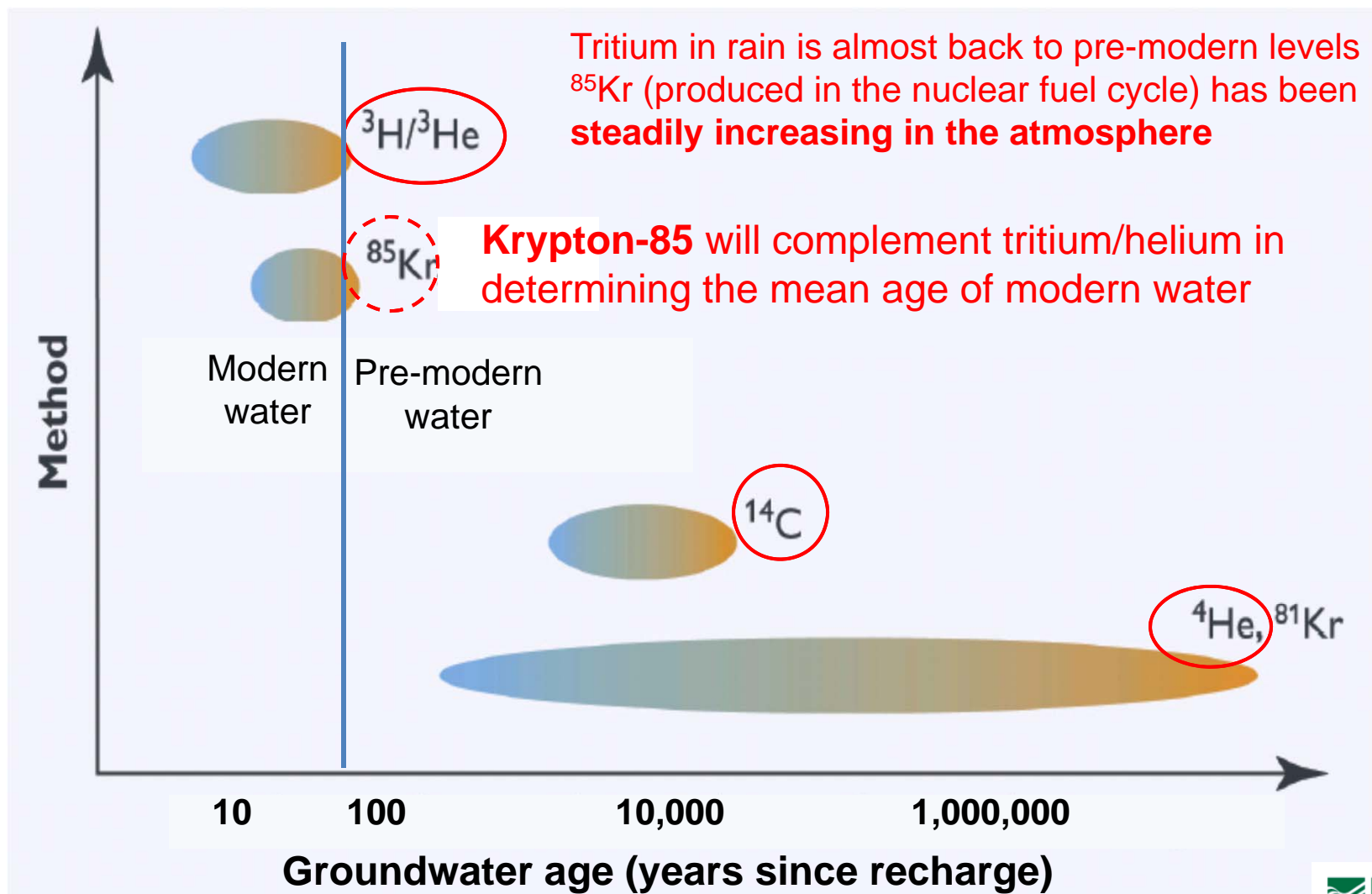


Age tracer studies that use tritium only should take into account the source of recharging water in constructing model ages or age classifications.

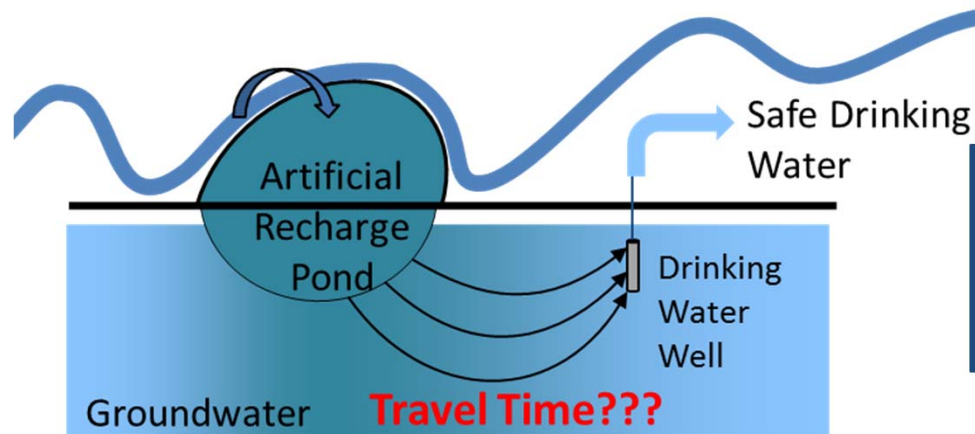
The GAMA program currently uses multiple age tracers:
Tritium/helium-3; radiocarbon; and radiogenic helium



GAMA Special Studies is also developing krypton-85 as a new tracer for dating modern water



Sub-theme: Age tracers for managed aquifer recharge



The use of treated wastewater used for groundwater recharge requires demonstrating a subsurface residence time of months to years.

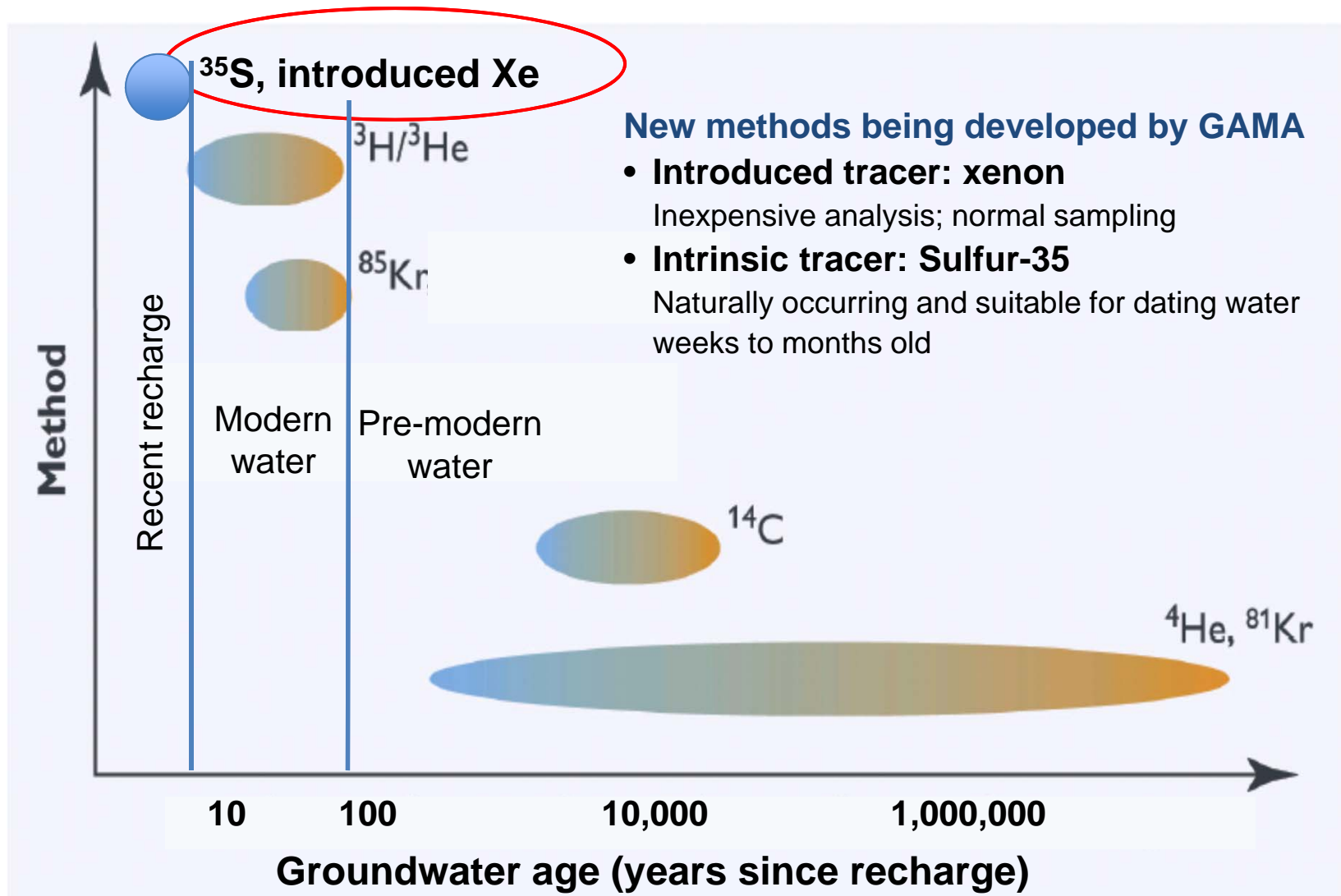
CDPH Guidelines

- **Intrinsic Tracer:** *Sample existing tracers.*
Demonstrate a retention time of **9 months**
- **Introduced Tracer:** *Track an added tracer.*
Demonstrate a retention time of **6 months**

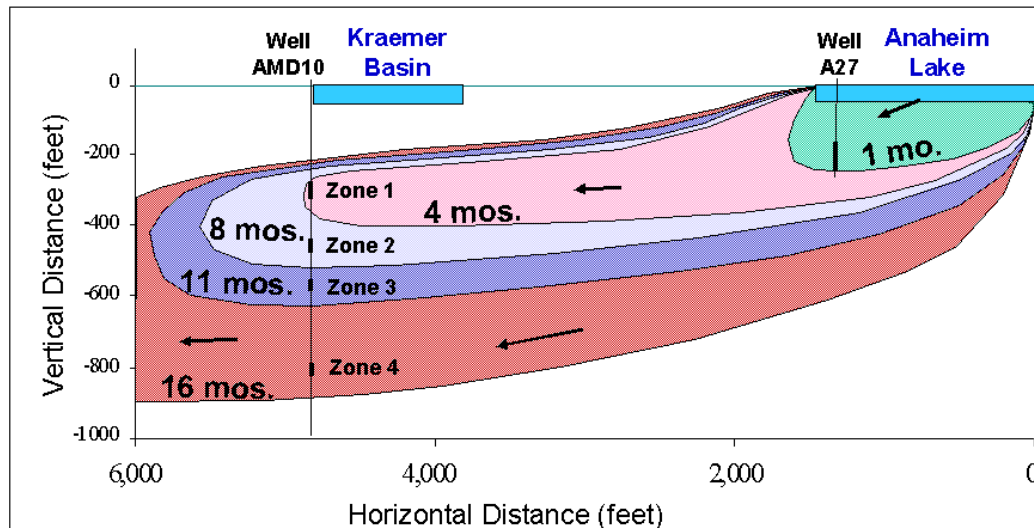
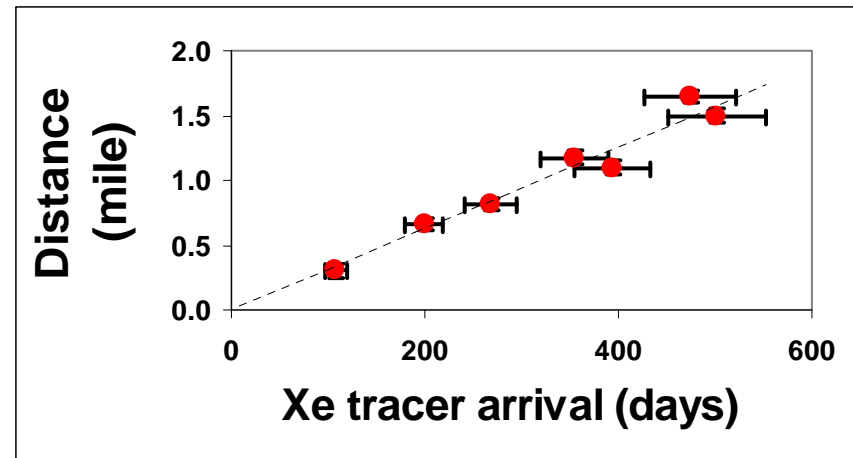
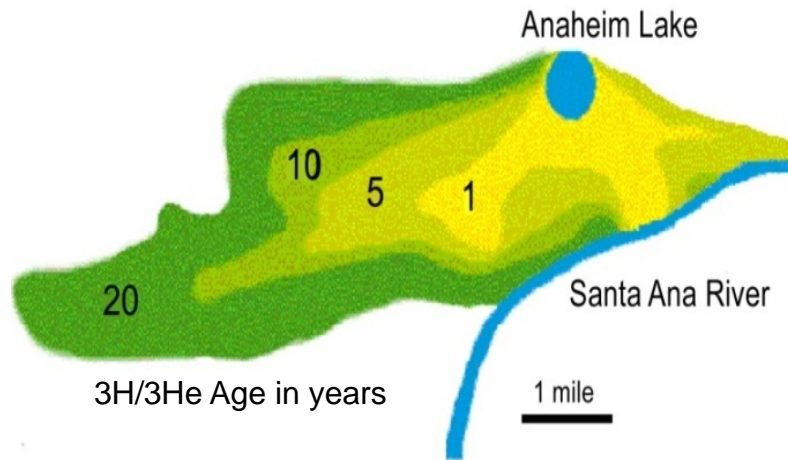
Current tracers are inadequate

- **Introduced: Sulfur hexafluoride (SF₆):**
Greenhouse gas; being phased out by CARB
- **Introduced: Isotopic noble gases:**
Limited and expensive analysis,
Specialized sampling
- **Intrinsic: Tritium/helium-3**
Cannot determine ages <1-2 years

GAMA Special Studies is developing new tracers to trace recent recharge

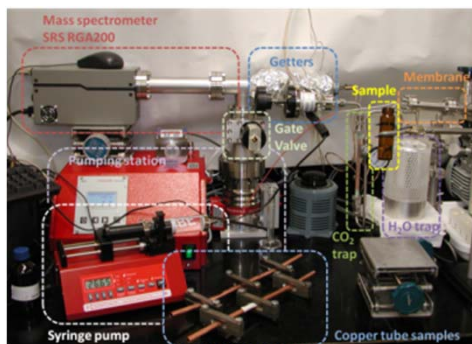


The old approach: Introduced isotopically-enriched noble gas tracers analyzed at LLNL by NGMS in a dedicated facility



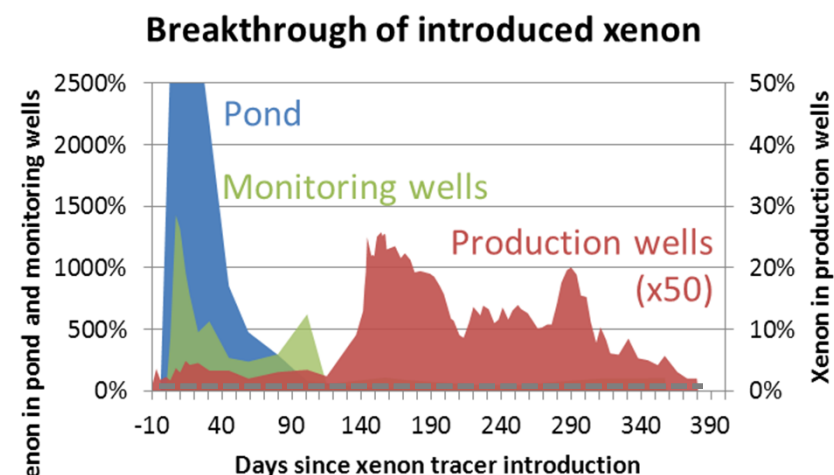
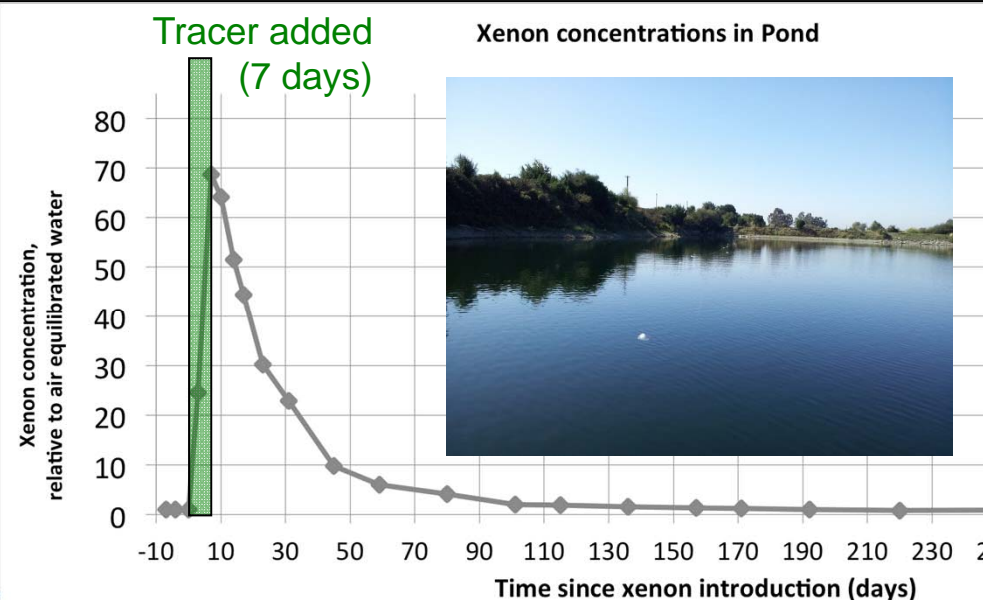
Analyses by NGMS at LLNL in a large room-sized facility run by a PhD-level scientist

The new approach: Introduced noble gas tracers analyzed on a small, simple Noble Gas Membrane Inlet Mass Spectrometer (NG-MIMS)



Fast analyses on a new **NG-MIMS** bench-top instrument made with commercial parts

- **The new approach is inexpensive:**
Xenon tracer studies at a similar cost to SF6,
- **Tracer introduction and sample collection are simple:**
Un-attended introduction at near 100% efficiency
Sample collection using standard methods
- **The new approach is sensitive:**
A small fraction (0.1%) of surface recharge water can be detected in drinking water production wells



Sub-theme: Managed aquifer recharge and water quality

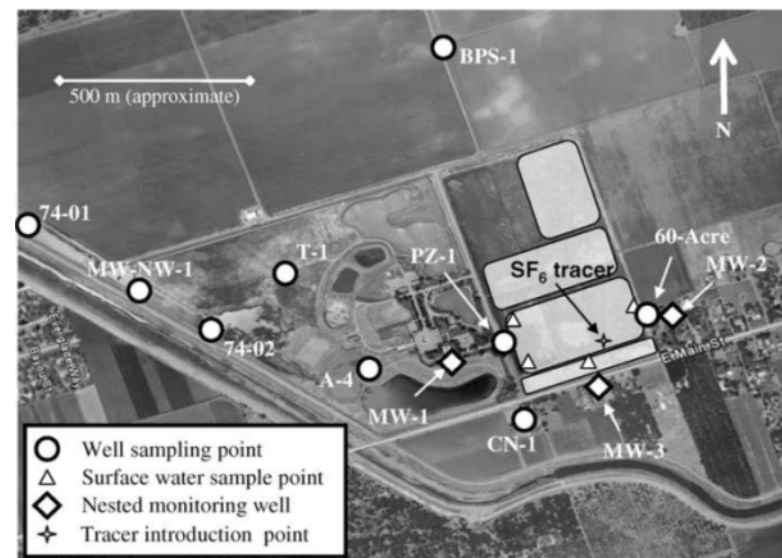
Investigated a groundwater banking project in California's Central Valley:

- Introduced SF₆ tracer
- Tritium/helium-3 age dating
- Geochemical modeling

Key Findings:

- **Identification of suitable areas**
- **Travel times** for banked water
- **Water quality changes** in banked high-quality water
- **Transport of emerging contaminants** associated with groundwater recharge

Managed Aquifer Recharge is vital for California's water supply

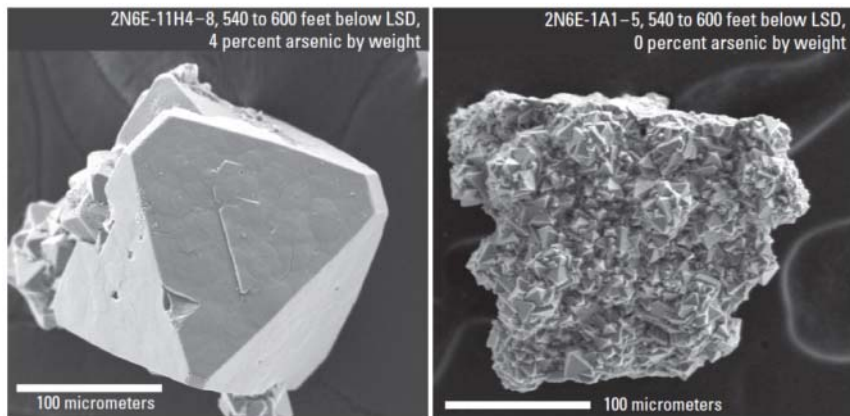


A key finding was that the highest groundwater arsenic concentrations occurred in the most recently recharged water.

Water quality can be affected by groundwater banking under specific recharge conditions

Arsenic release is controlled by local geology and the composition of the recharge water

- Arsenic is rapidly released from naturally occurring iron oxides in the aquifer to recharge waters, which have higher pH than ambient water



Izbicki et al. 2008. USGS OFR-2008-1272.

Specific recommendations can be made on recharge management

- Low-oxygen conditions during recharge will result in dissolution of ferric oxides, and release of much higher concentrations of arsenic.
- High oxygen demand in recharging water should be avoided.
- The current operation is sustainable with monitoring

McNab WW, Singleton MJ, Moran JE, and Esser BK, 2009. Ion exchange and trace element surface complexation reactions associated with applied recharge of low-TDS water in the San Joaquin Valley, California. *Applied Geochemistry* **24**, 129-137.

Water quality changes associated with managed aquifer recharge operations can be managed.

Sub-theme: Groundwater recharge & vulnerability

California Aquifer Susceptibility Project (SWRCB/USGS/LLNL) – the first GAMA Project

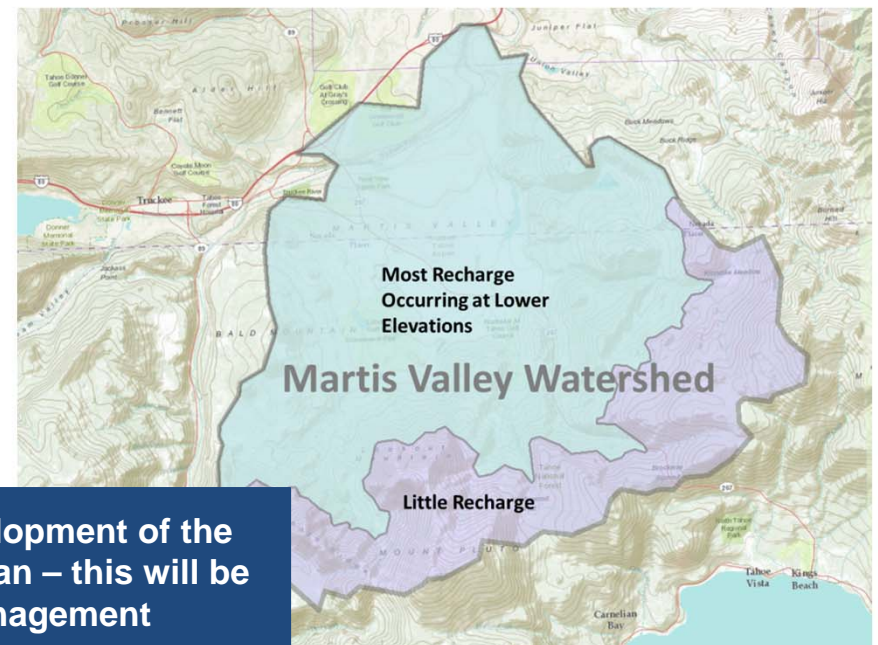
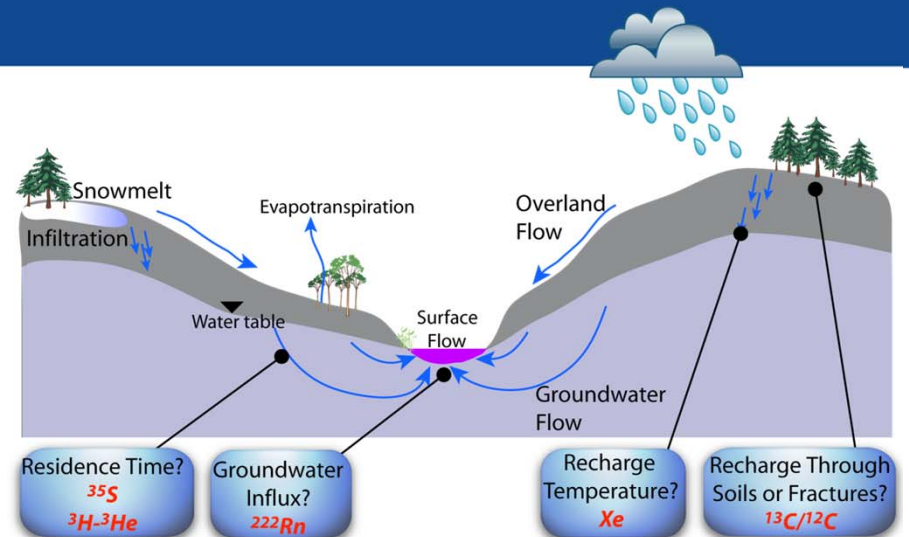
- **Groundwater age as a proxy for susceptibility**
- Coastal aquifers are well-protected
- Central Valley aquifers are more vulnerable

Climate change and groundwater

- How will changes in the type and timing of precipitation affect recharge, runoff and water quality in high-elevation headwater basins?

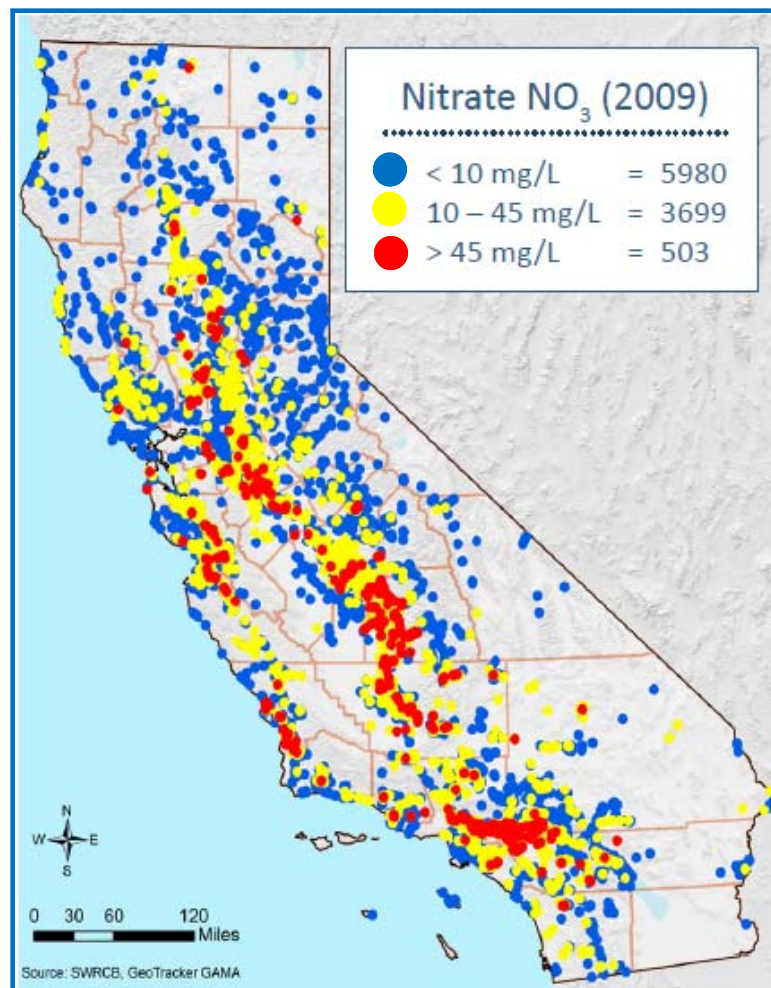
GAMA Special Study: Martis Valley, a headwater basin

- Consider climate change impacts to groundwater recharge & groundwater quality
- Determine primary recharge locations & their vulnerability
- **Collaboration** with research institutions (DRI, UNR), and local water agencies (PCWA, TDPUD, NCSD)



This work is providing age tracer constraints on development of the Martis Valley Groundwater Model and Management Plan – this will be a model for the use of age tracers in groundwater management

Theme: Multi-tracer studies of groundwater nitrate (a water-quality issue of state-wide relevance)



Addressing Nitrate in California's Drinking Water

With a Focus on Tulare Lake Basin and Salinas Valley Groundwater

Report for the State Water Resources Control Board Report to the Legislature



California Nitrate Project,
Implementation of Senate Bill X2.1

Center for Watershed Sciences
University of California, Davis
<http://groundwaternitrate.ucdavis.edu>

Prepared for the California State Water Resources Control Board

Nitrate-contaminated groundwater case studies

Two case studies where shallow groundwater has high nitrate

- **Chico:** Deeper groundwater is primary source of drinking water
- **SJV Dairy:** Deeper groundwater has lower nitrate or no nitrate



What is the source & age of the contamination?

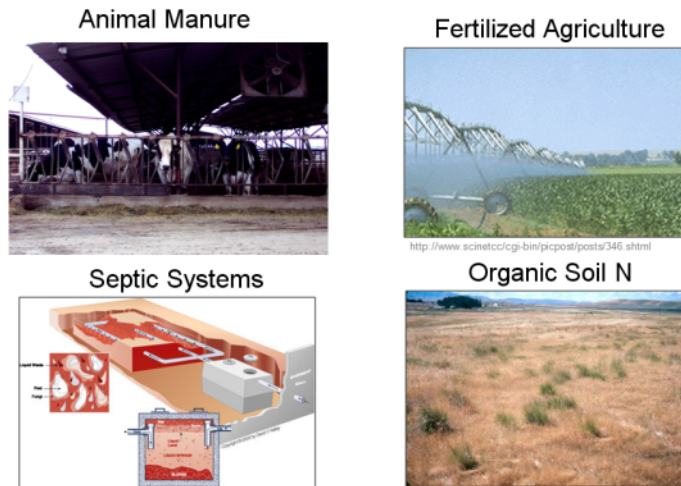
- High-density septic systems?
- Legacy or current agricultural practices?

What does the future hold?

- Will nitrate in shallow water move to deep wells?
- Is nitrate being degraded during transport?

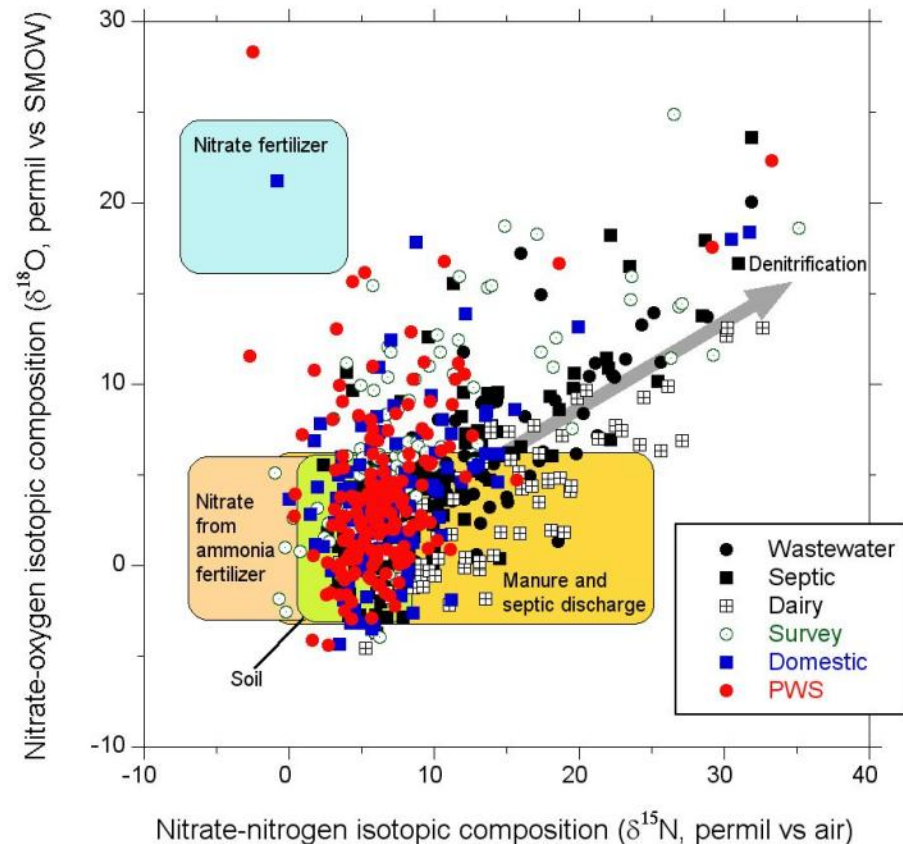
Using an isotopic approach to distinguish nitrate source: Synthetic fertilizers, manure, soil, wastewater?

The dual-isotope approach can distinguish synthetic fertilizers from organic N sources, but cannot distinguish manure from septic sources



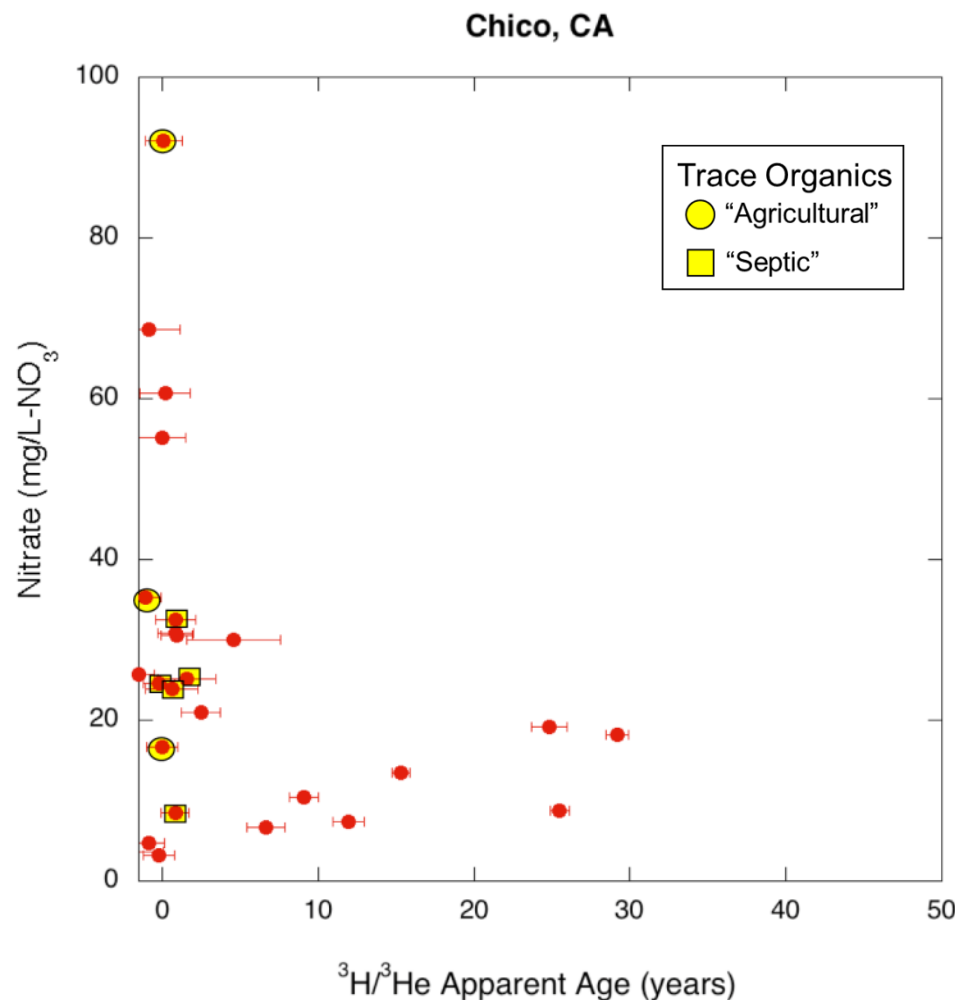
Nitrate from Chico & the SJV Dairy falls in the “manure and septic discharge” field.

Nitrogen & oxygen isotopic composition of nitrate in GAMA Special Study groundwaters



Nitrate isotopic composition data can be used to provide an independent assessment of nitrate source to shallow groundwater.

First-encounter groundwater nitrate in Chico is recent and is from both agricultural and septic sources



Nitrate contamination in Chico

- High-density septic system discharge is a source of nitrate within the city limits
- Manure is a source of nitrate on the periphery of the city
- Nitrate contamination is ongoing and associated with current practices

We used a similar approach to distinguish nitrate sources in the Livermore-Amador Basin:

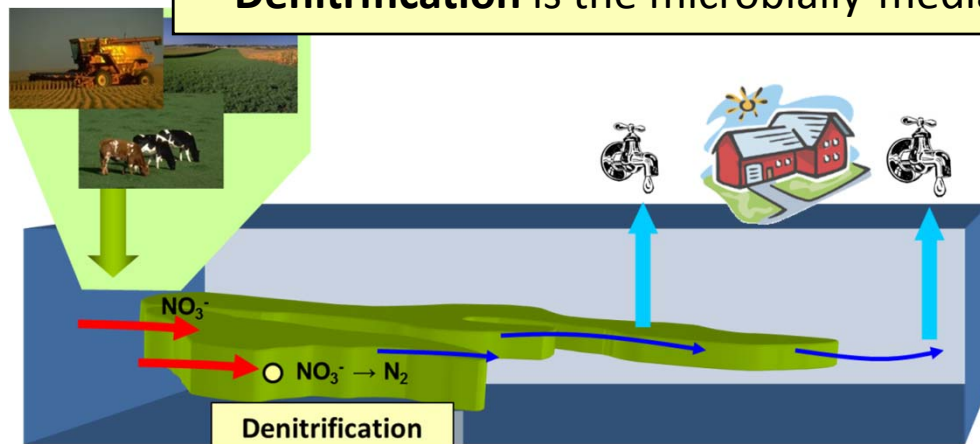
The International Association of GeoChemistry selected the paper – “Moore et al. (2006) *Sources of Groundwater Nitrate Revealed Using Residence Time and Isotope Methods*” -- as the year’s most significant paper published in *Applied Geochemistry*, the IAGC’s monthly scientific journal.

- Groundwater age dating can distinguish recent from legacy nitrate.
- Trace organics can distinguish septic from agricultural nitrate

Nitrate-contaminated water: Transport

Will nitrate in shallow aquifers show up in deep aquifers?

Denitrification is the microbially-mediated conversion of nitrate to nitrogen gas.

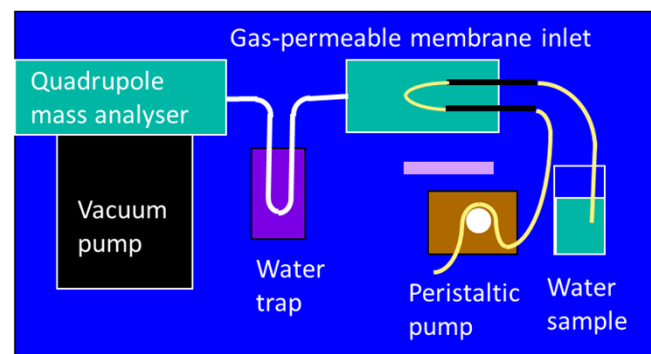


- Does denitrification provide a sink for nitrate in California aquifers?
- Will high nitrate in shallow aquifers reach deeper aquifers?

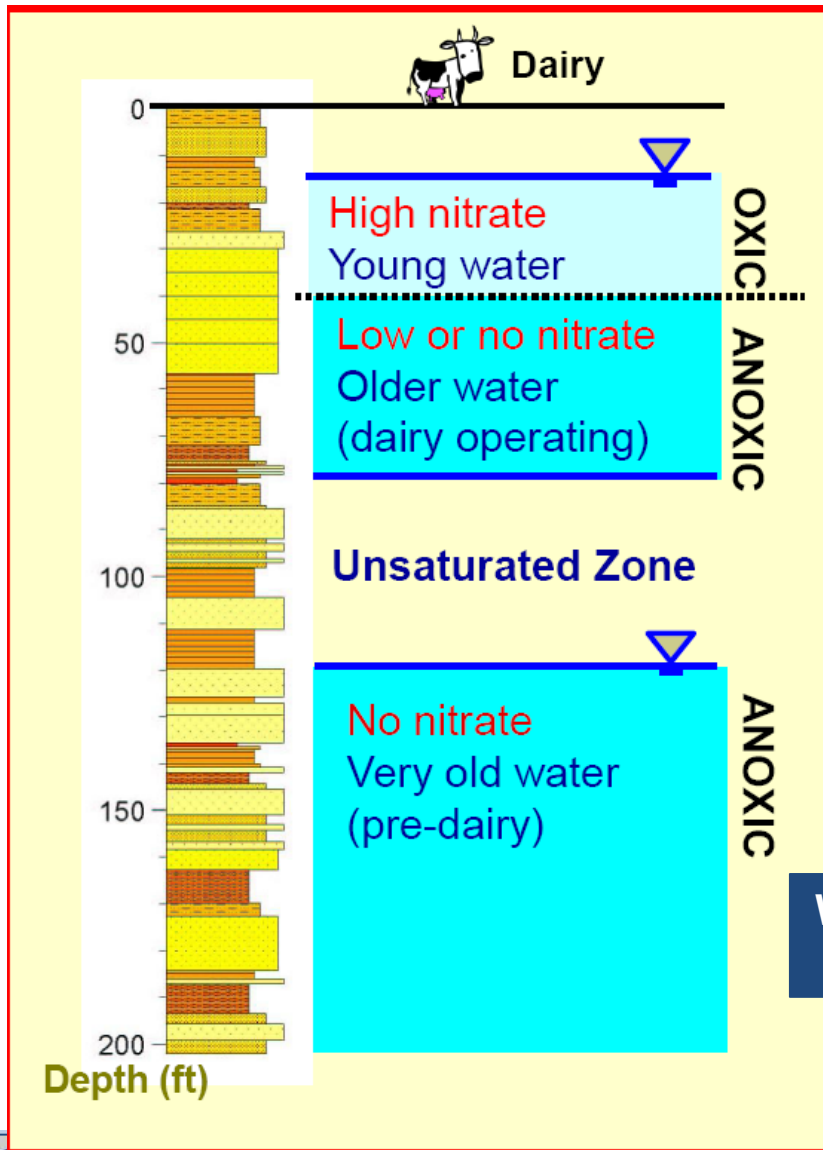
LLNL built a small gas analyzer to measure nitrogen in groundwater and to quantify denitrification

Membrane inlet mass spectrometry (MIMS)

- Fast, field-portable, and inexpensive
- Standard sampling: VOA vials



A GAMA Special Study used a dairy in the southern San Joaquin Valley as a case study of dairy impacts on underlying groundwater



Shallow Local Aquifer

- *Active denitrification protects deeper water in the local aquifer*
- Nitrate source is dairy operations:
Young water and isotopics consistent with manure

Deeper Regional Aquifer

- *Long flow paths protect deeper aquifer*
- Not impacted by dairy operations:
Very low initial nitrate and very old age

We were able to assess denitrification by using MIMS analyses of excess nitrogen.

Salinas Valley nitrate study



Basemap from Kulongoski et al., 2005

Study Questions:

- What is the natural background nitrate concentration for the study area?
- What happens to nitrate in the Salinas River during recharge and transport?
- What is the source of nitrate in a contaminated drinking water wells?

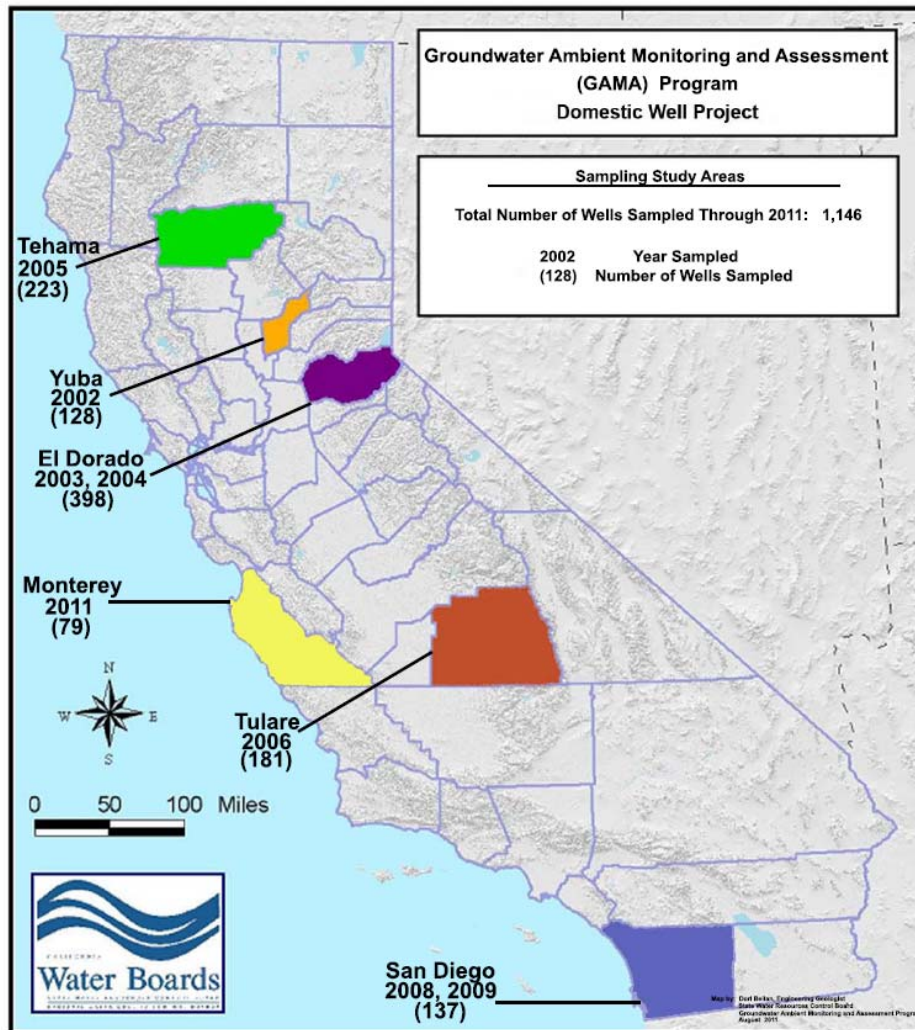
Study Findings

- When rainwater and soil are the only source of N, groundwater nitrate is very low ($< 4\text{ppm}$)
- Groundwater from shallow & deep wells adjacent to the river has recharged relatively recently. Older water is found in the confined zone and in the Eastside subbasin
- Denitrification is taking place in the vadose zone and in groundwater near the Salinas R.
- The San Jerardo community well draws high-nitrate irrigation return water in the spring and summer.

Moran (2011) Nitrate Fate and Transport in the Salinas Valley: Presentation to Region 3 Board (San Luis Obispo; 09/01/2011).

GAMA Special Studies complement and inform Priority Basin Studies

GAMA Special Studies also supports the Domestic Well Project



- **LLNL analyses**

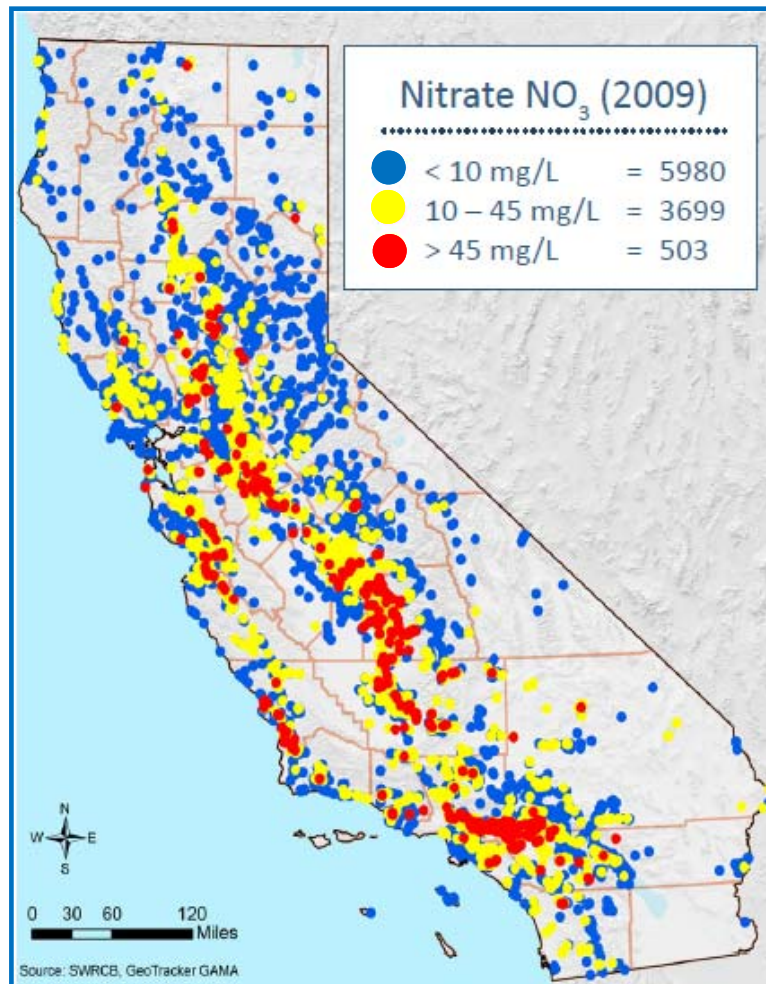
- Isotopic composition of water
- Isotopic composition of nitrate
- Isotopic composition of boron

- **Tulare County**

- >40% of wells exceed nitrate MCL
- **Isotopic data consistent with findings of SBX2 report (Harter et al, 2012):**
 - *Water isotopes indicate most domestic well water is from irrigation returns*
 - *Nitrate isotopes are consistent with a mixed source of synthetic and organic fertilizer*

Capabilities developed by Special Studies are leveraged by other GAMA Projects

Theme: Leveraging age tracer data in the GAMA dataset



The GAMA dataset and Geotracker GAMA are incredible resources

GAMA Special Studies is developing an age tracer database for upload to Geotracker GAMA

- Phase I: Upload archival tritium and noble gas data from GAMA Special Studies and California Aquifer Susceptibility Projects to Geotracker

Tritium, helium isotopic, and noble gas concentration data allow calculation of

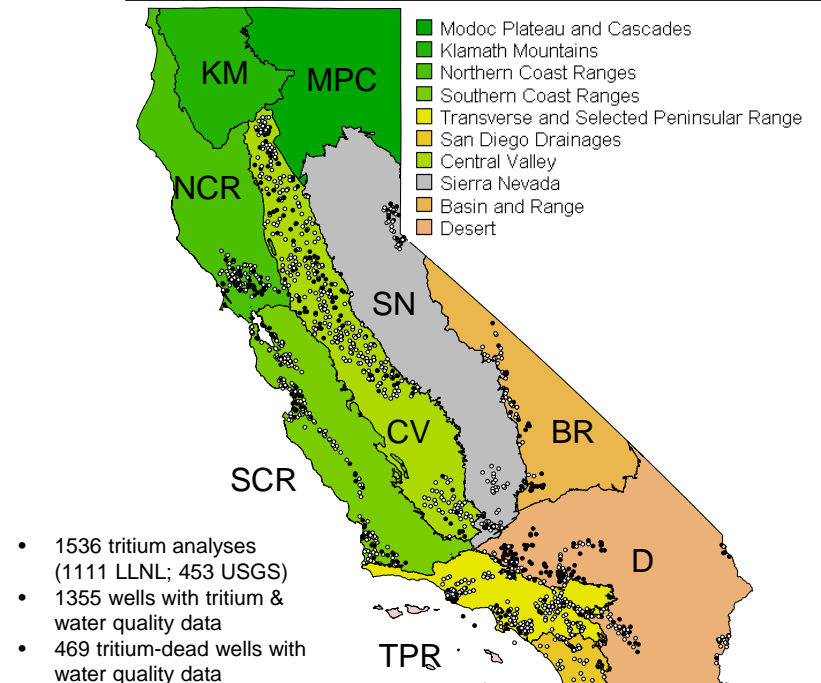
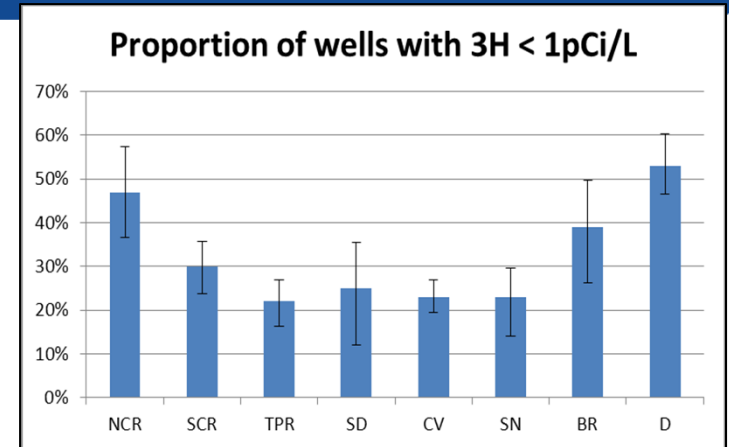
- Mean groundwater age: Tritium/helium-3
- Fraction pre-modern: Initial tritium
- Recharge temperature: Xenon
- Excess air (recharge condition): Neon

Recent Special Studies have focused on leveraging the data collected by the GAMA Program (California Aquifer Susceptibility, Priority Basin, Domestic Well and Special Studies projects)

Example: **Can we use groundwater age to estimate “pre-modern” nitrate levels in ambient groundwater?**

Using groundwater age to estimate “pre-modern” water quality in ambient groundwater

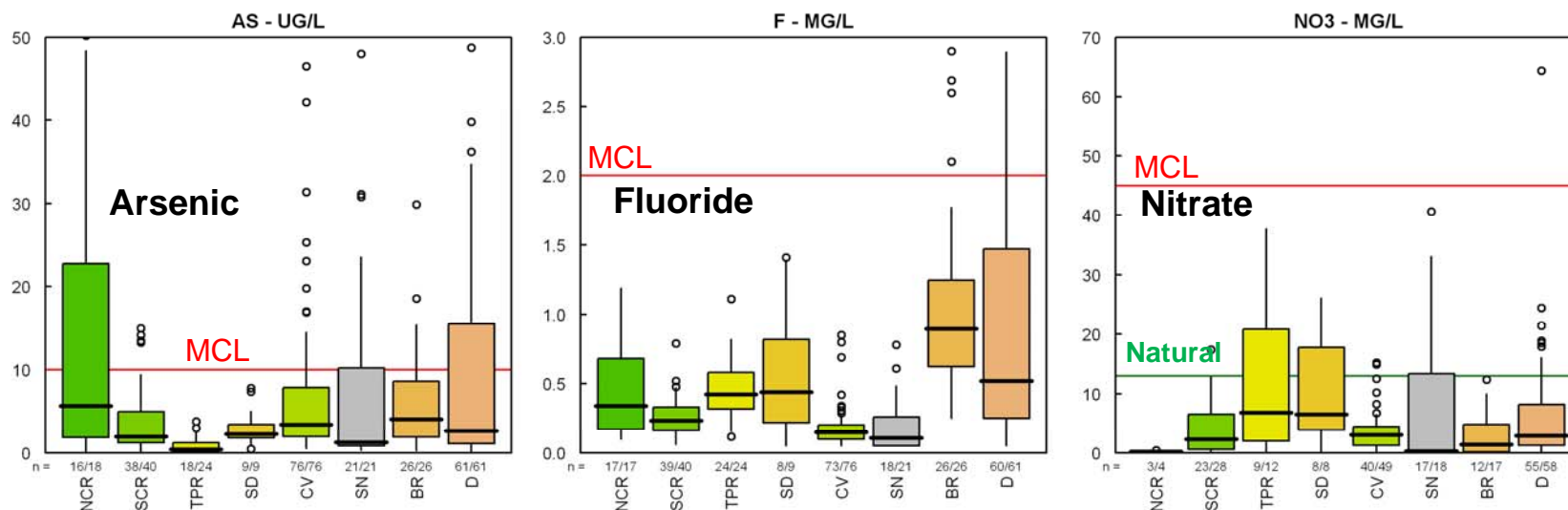
- **Define “pre-modern” as < 1 pCi/L tritium**
 - Most wells have a modern water recharge component (similar to the finding of Belitz et al, 2010, 2011)
- **Group results by Priority Basin “province”**
 - The proportion of tritium-dead wells by province varies from less than 25% to greater than 50%.
- **Investigate natural & anthropogenic constituents**
 - Nitrate, arsenic, fluoride
 - Pesticides and VOCs
- **Consider groundwater redox state**
 - Eliminate samples where denitrification might occur



- 1536 tritium analyses (1111 LLNL; 453 USGS)
- 1355 wells with tritium & water quality data
- 469 tritium-dead wells with water quality data

Pre-modern groundwater quality varies by province and by constituent

- **Old groundwater has high concentrations of naturally-occurring constituents**
 - One quarter (26%) of the wells have at least one constituent above MCL, SMCL, or NL*
 - Most exceedances are for naturally-occurring constituents (As, F) – this supports the findings of the Priority Basin Study on the significance of naturally contaminants.
- **Background nitrate concentrations are “low” and vary by province**
 - Nitrate is not found above the MCL in pre-modern wells (one exception)
 - Pre-modern nitrate is on average lower than “natural” levels cited in the literature



*The wells are not affected by small fractions of highly contaminated “modern” water (only 4% have a detectable “modern” contaminant, e.g. MTBE)

Theme: What are the general findings?

- **Age is one of the key factors controlling groundwater quality => *Groundwater age tracers are valuable tools***
 - as a predictor of groundwater susceptibility
 - as a constraint on groundwater flow (e.g. managed recharge)
- **Multi-tracer approaches provide a scientific basis for contaminant source attribution and new information for water management**
 - Managed aquifer recharge can impact water quality
 - Contaminant attribution often requires multiple tracers
 - Contaminant transport is essential to predict impact on deeper aquifers used for public drinking water
- **To address California's water quality and supply issues, we need **measurements!!!****
 - Consistent well-documented datasets (like the Priority Basin program) are exceptionally valuable, especially when combined with supporting isotope data

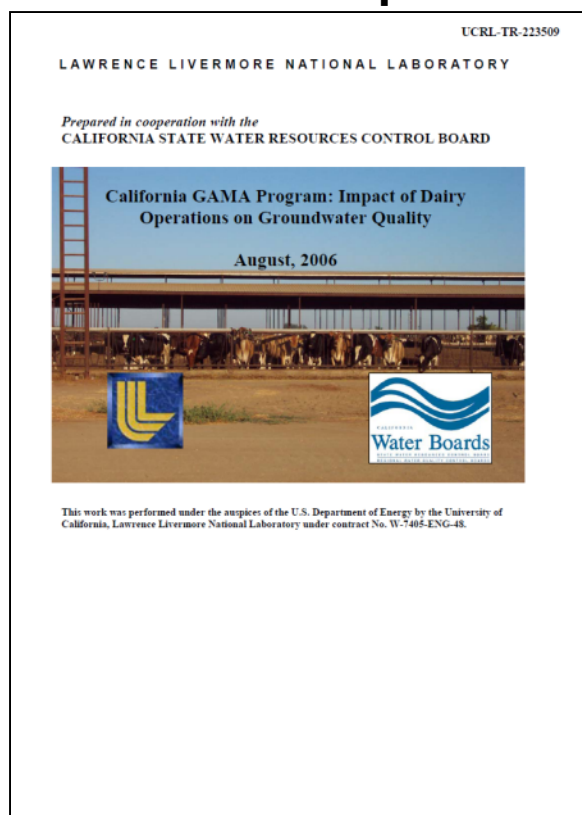
Vision for the future of Special Studies

- **Managed Aquifer Recharge, Indirect Potable Reuse, and Groundwater Banking Sites**
 - Focus on young water using age & water quality tracers
 - New age tracers: Kr-85 (0-50 years), S-35 (0-2 years)
 - Identify “sweet spots” for water banking
 - Make age tracers more widely accessible
 - Develop new data interpretation tools and approaches
 - Develop new instruments for faster & less expensive analysis (e.g. NG-MIMS)
 - Provide workshops & tech transfer to public agencies, regulatory agencies, and consulting companies
- **Continue to develop tracers and case studies for contaminant attribution & transport**
 - Managed aquifer recharge impacts on water quality
 - Forecasting shallow water quality to deeper water production wells
 - Documenting impact of changes in water or land management on groundwater quality
- **Mine the GAMA dataset and enhance its utility to water resource managers**
 - Identify areas where groundwater is being extracted unsustainably
 - Identify areas where denitrification is likely to decrease nitrate concentrations
 - Deconvolve mixtures at drinking water production wells

Focus on the most vulnerable aspects of the groundwater system: shallow aquifers. Use age tracers to guide the use of limited resources in characterizing groundwater.

Technical Publications

Technical Reports



20 published (as of 03/2013)
www.swrcb.ca.gov/water_issues/programs/gama/gamadocs.shtml

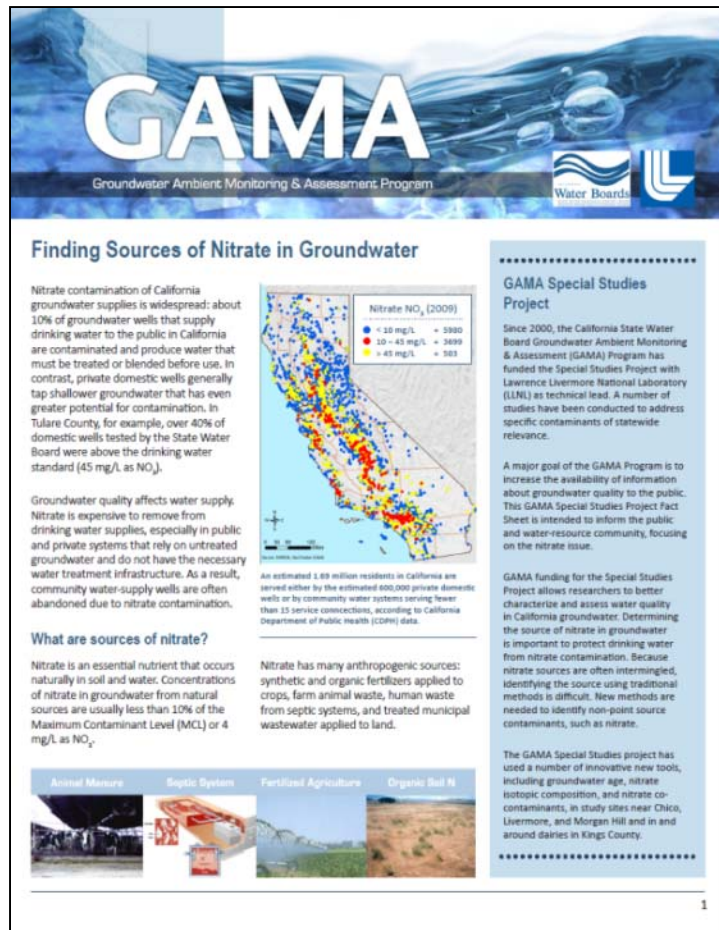
Peer-reviewed Publications



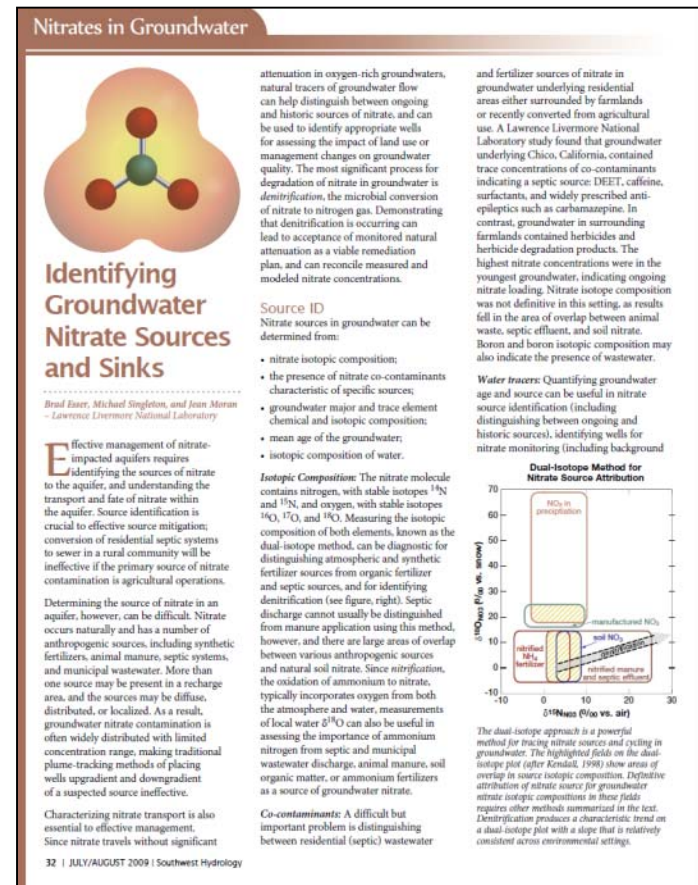
10 published (as of 03/2013)
Environmental Science & Technology
Applied Geochemistry
Ground Water
Water Resources Research

General Audience Publications

Fact Sheets



Non-technical publications



1 published, 1 in review

Southwest Hydrology
EPA Technology News & Trends
Hydrovisions

Presentations

Regulatory agency briefings

<p>Determining Sources of Nitrate in Groundwater Using Nitrate Isotopic Composition</p>
<p>Presented to: Regional Water Quality Control Board Groundwater Monitoring Alternatives at Dairies September 4, 2008 (Rancho Cordova)</p> <p>Bradley K. Esser Lawrence Livermore National Laboratory SWRCB GAMA Program</p> <p><small>This work was performed under the auspices of the U.S. Department of Energy by the University of California Lawrence Livermore National Laboratory under Contract No. DE-AC52-07NA27344.</small></p>

Scientific conferences

Toward Sustainable Groundwater in Agriculture

An International Conference Linking Science and Policy

ABSTRACTS NOW BEING ACCEPTED

June 15-17, 2010
Hyatt Regency at the San Francisco Airport
Burlingame, CA

With additional Groundwater Workshops on June 14
and an Agricultural Groundwater Tour on June 18

Stakeholder & professional workshops & meetings

HYDROVISIONS

Volume 15, No. 3 GROUNDWATER RESOURCES ASSOCIATION OF CALIFORNIA Fall 2006

Nitrate in California Groundwater Symposium 2006: Are We Making Progress?

BY BRAD ESSER, LAWRENCE LIVERMORE NATIONAL LABORATORY

INSIDE	
President's Message	2
Upcoming Events	3

Over 170 people attended the 17th Symposium in the Groundwater Resources Association of California Series on Groundwater Contaminants which was held on April 4 and 5, 2006 in San Joaquin Valley city of Modesto. The symposium was held in conjunction with a Dairy Groundwater Monitoring Workshop, an a GRA San Joaquin Valley branch meeting, and all addressed the longstanding problem of nitrate contamination in California groundwater.

The symposium brought together 25 speakers, 15 poster presentations, and moderators to try and answer "Nitrate in California: Are We Making Progress?" of approaches to answering is reflected in the program.

The Groundwater Resources Association of California is dedicated to resource management that improves groundwater education and technical leader

Dairy Groundwater Workshop

Groundwater Monitoring Regulations for Dairies, Monitoring Well Construction, and Monitoring Network Design

WORKSHOP

Clay Rogers
Central Valley Regional Water Quality Control Board
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Thomas Harter, Ph.D.
University of California, Davis
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Till Angermann
Lubdorff & Seidemann Consulting Engineers
ph:530-661-0109; tsausermann@LSECE.com

December 8, 2010
Stanislaus County Agricultural Center, Modesto, CA

ORGANIZED BY:
Univ. of California Cooperative Extension - Groundwater Hydrology Program
<http://groundwater.ucdavis.edu/>

UC DAVIS
UNIVERSITY OF CALIFORNIA

Acknowledgements

LLNL GAMA Project Members

Richard Bibby, Steve Carle, Wayne Culham,
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Sarah Roberts, Ate Visser

LLNL GAMA Students

Colleen Barton, Heath Bigman, Brad Cey,
Christopher Cox, Elizabeth DeRubeis,
Stephanie Diaz, Marianne Holtz, David Meier,
Daniel Segal, Crystal Tulley

Agency Collaborations

SWRCB (State & Regional)
US Geological Survey
California Department of Water Resources
California Department of Public Health
UC Cooperative Extension
Numerous Water Districts
Numerous Well Owners

LLNL Student Programs

LLNL Summer Intern Program
LLNL Postdoctoral Program

University Collaborations

California State University, East Bay
University of California, Davis
University of California, Merced
University of California, Santa Barbara
University of Arizona
University of Texas, Austin



Technical Reports

(as of 03/2013)

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For more information

State Water Board GAMA Program Website:

<http://www.waterboards.ca.gov/gama>

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GAMA Priority Basin Project 2004-2013

Miranda Fram, Program Chief
and the USGS-GAMA Team of 20 hydrologists,
technicians, and students

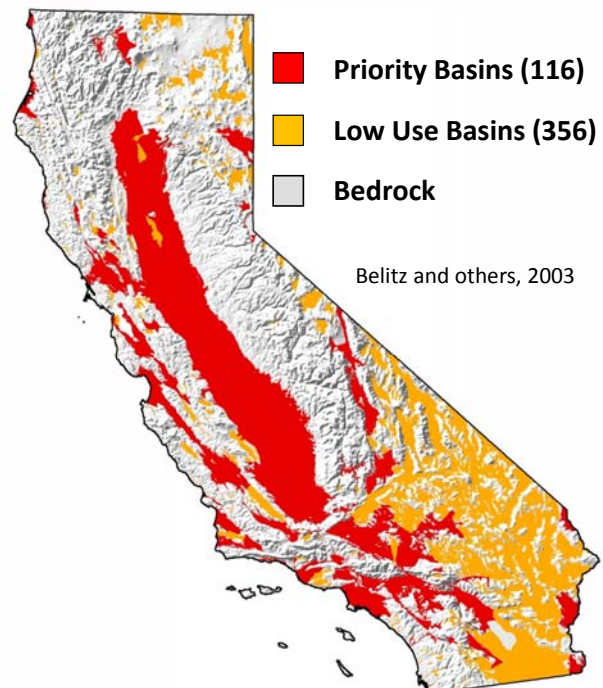
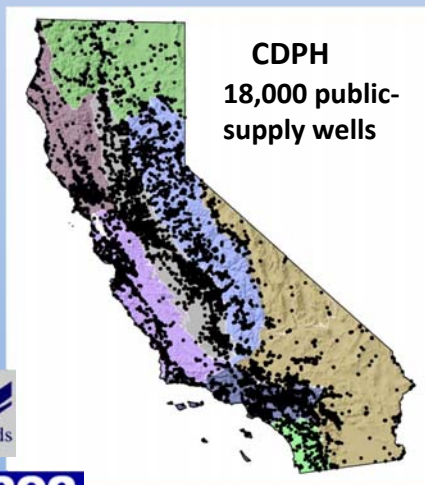
USGS California Water Science Center

Presentation to GAMA Public Advisory Committee
April 30, 2013



GAMA Priority Basin Project (PBP): Design

***AB599: focus on basins
(aquifers) that provide
drinking water***



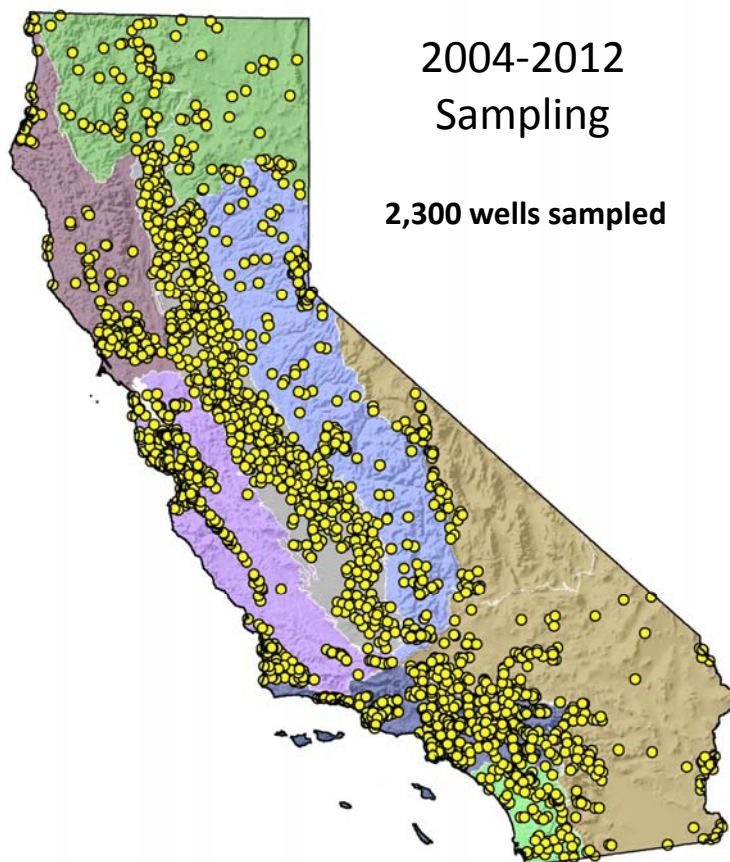
GAMA PBP: Implementation

Focus on depth zone
used for public supply

Assessed 95% of used
resource

35 GAMA-PBP study
units included:

- 116 Priority Basins
- 75 Low-Use Basins
- 8 areas outside of basins



2004-2012
Sampling

2,300 wells sampled

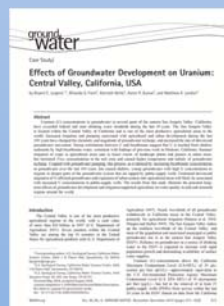
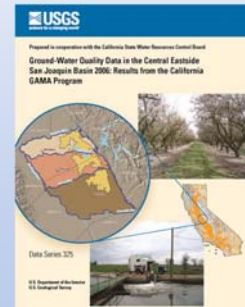
GAMA PBP: Assessments

- Status of groundwater quality at the basin, regional, and statewide scale
 - Spatially unbiased statistical methods
 - Uses USGS-GAMA and CDPH data
- Understanding of natural and anthropogenic factors affecting groundwater quality
 - Statistical correlations with potential explanatory factors (e.g., land use, aquifer lithology, groundwater age, pH, redox, depth, position in groundwater flow system, etc.)
 - In-depth assessments of processes and individual constituents



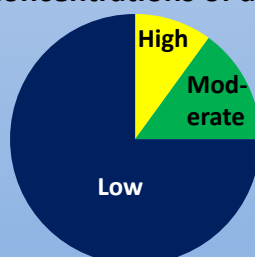
GAMA PBP: Products

- Study unit reports – Data Report, Assessment Report, and Factsheet for each study unit
- Synthesis reports – regional assessments, quality control
- Scientific journal articles – in-depth studies of particular constituents or processes



GAMA PBP: Presentation of Results

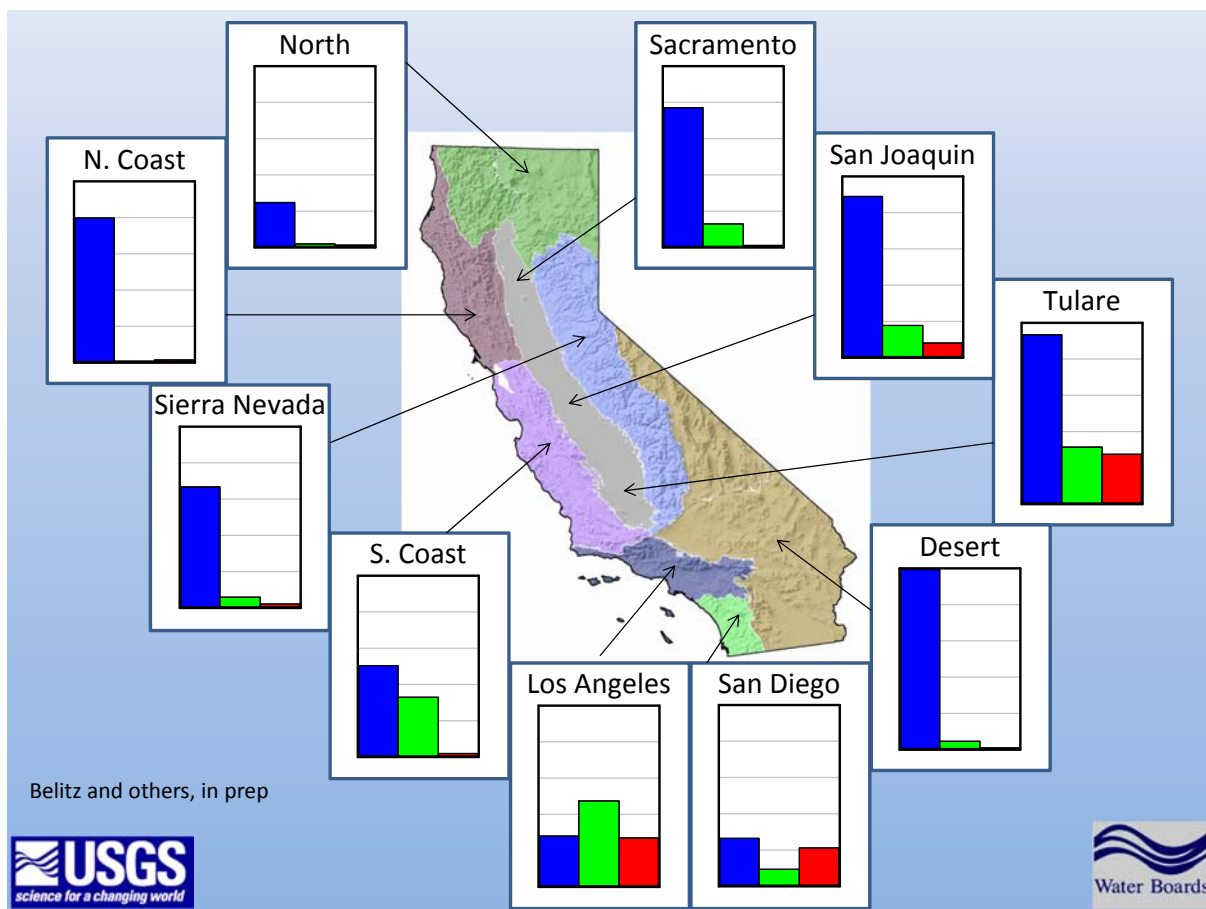
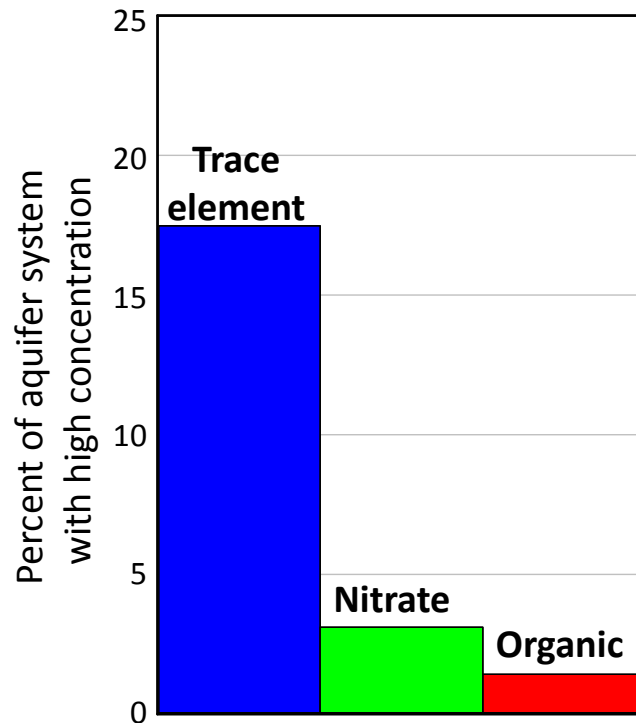
- Use relative-concentrations and aquifer-scale proportions to put results in context and facilitate comparisons between constituents and areas
- Relative-concentration (RC): measured concentration divided by benchmark concentration
 - High – $RC > 1$ (concentration above benchmark)
 - Moderate – $RC > 0.5$ (inorganics) or $RC > 0.1$ (organics)
 - Low – RC below moderate or not detected
- Aquifer-scale proportion: areal proportion of aquifer system with “high”, “moderate”, or “low” concentrations of a constituent or class of constituents



GAMA PBP: Statewide Summary

A greater proportion of public-supply aquifers have high concentrations of one or more trace elements than have high concentrations of nitrate or of one or more organic constituents

Belitz and others, in prep

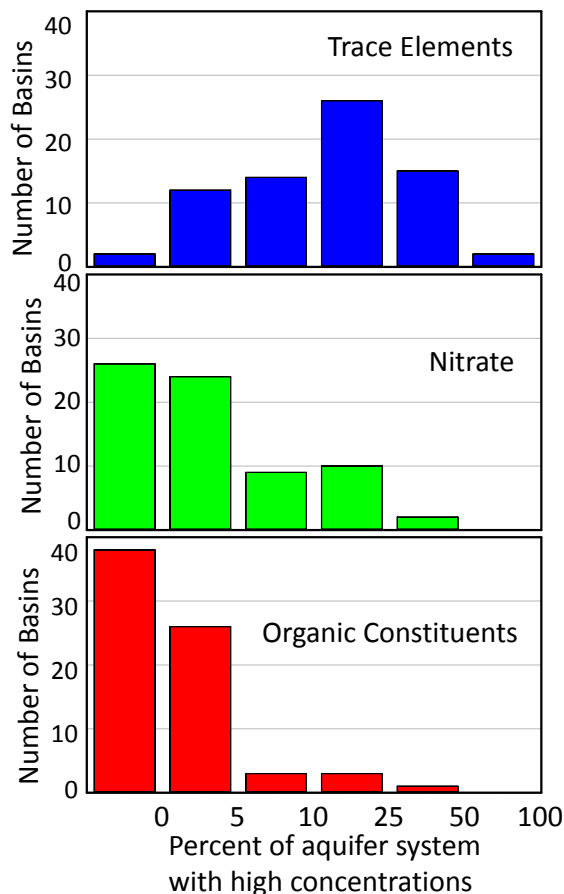


Basin Scale

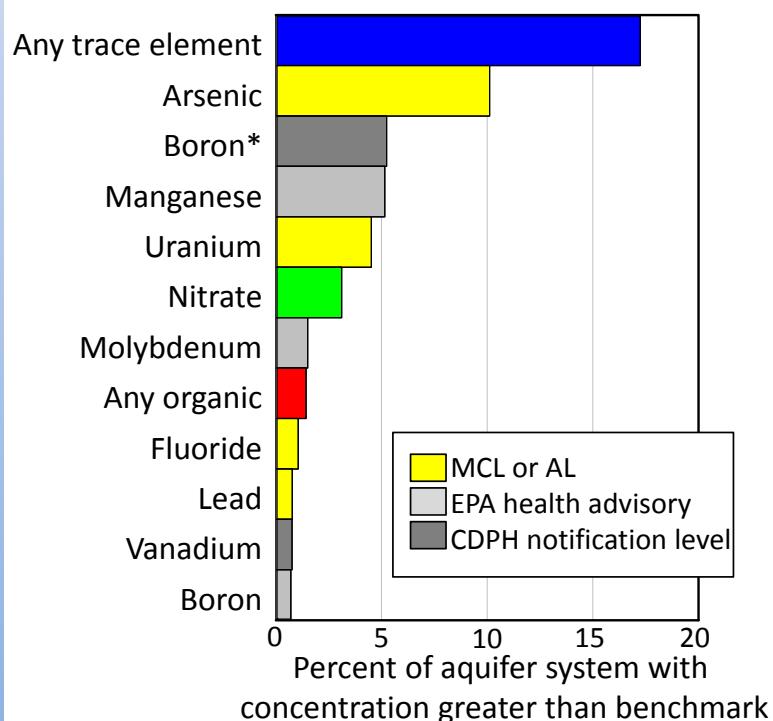
Basins with > 25% prevalence of high concentrations of trace elements are in Desert, Central Valley, and S. Coast Ranges.

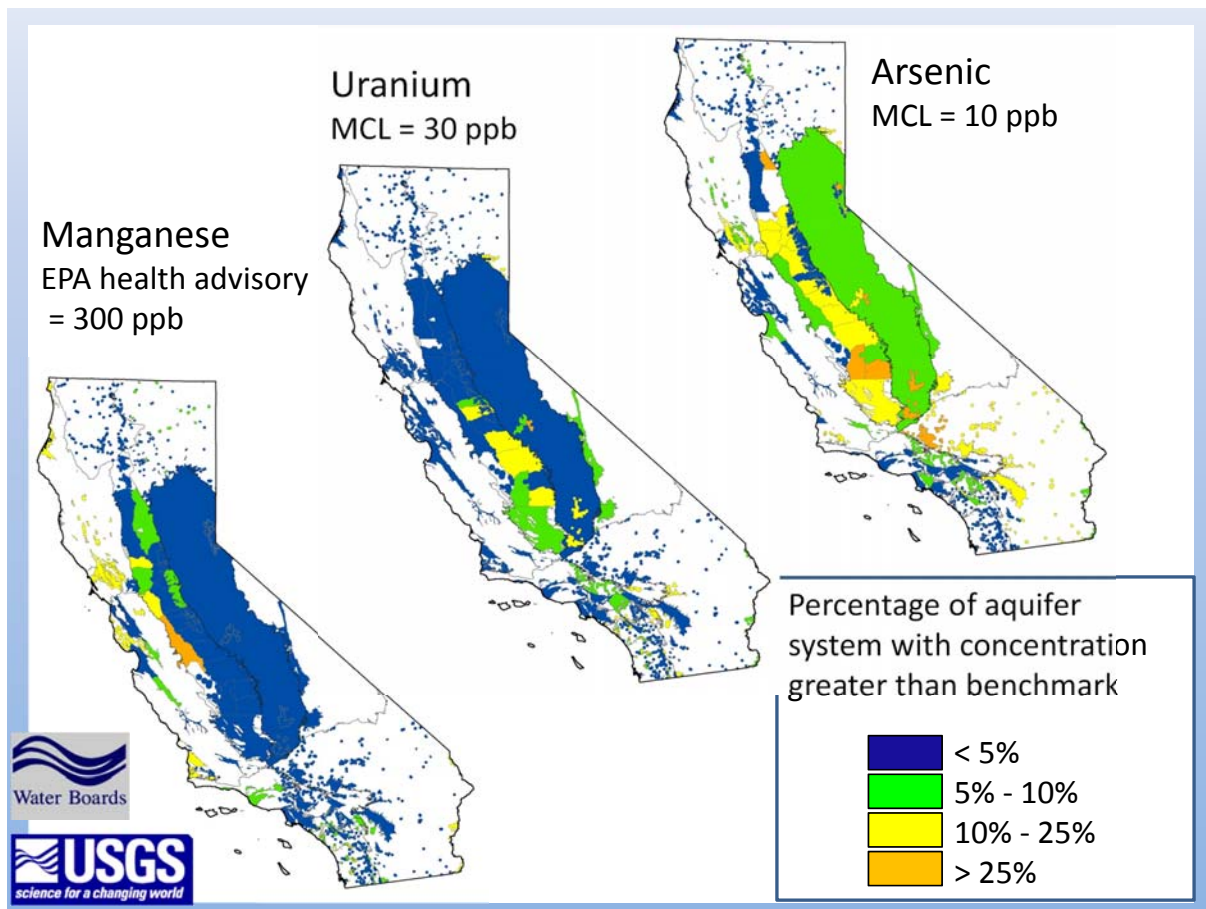
Basins with > 10% prevalence of high concentrations of nitrate are in Los Angeles region, S. Coast Ranges, and Tulare Basin.

Basins with > 5% prevalence of high concentrations of organics are in Los Angeles region (mainly solvents) and Tulare Basin (fumigants).



GAMA PBP: Statewide Summary





GAMA PBP: In-Depth Studies – Inorganic constituents

- **URANIUM** in the Eastern San Joaquin Valley/Tulare Basin [Jurgens and others, 2010]
- **ARSENIC** in the Napa and Sonoma Valleys [Forrest and others, 2013]
- **NITRATE** and **TOTAL DISSOLVED SOLIDS** in the Upper Santa Ana watershed basins [Kent and Landon, 2012]
- **NITRATE** in the Central Eastside San Joaquin Valley [Landon and others, 2011]

GAMA PBP: In-depth studies – organic and special-interest constituents

- **PERCHLORATE** – Statewide distribution [Fram and Belitz, 2011]
- **PHARMACEUTICALS** – Statewide distribution [Fram and Belitz, 2011]
- **BENZENE** – Geogenic sources [Landon and Belitz, 2013]
- **VOCs** – Occurrence of very low concentrations [Deeds and others, 2012]



GAMA Priority Basin Project 2004-2013 Summary

- **Sampled 2,300 wells for comprehensive assessment of 95% of California's groundwater resources used for public drinking water supply**
- **Quality of entire resource evaluated**
 - Major contaminants identified
 - Areas with high and low concentrations identified statewide
- **Anthropogenic and natural processes contributing to high concentrations evaluated**
 - Explanation of where and why concentrations are high
- **Statewide baseline of groundwater quality conditions established**
 - Trends evaluated relative to baseline





Questions?



GAMA Priority Basin Project 2013-2024

USGS Proposal



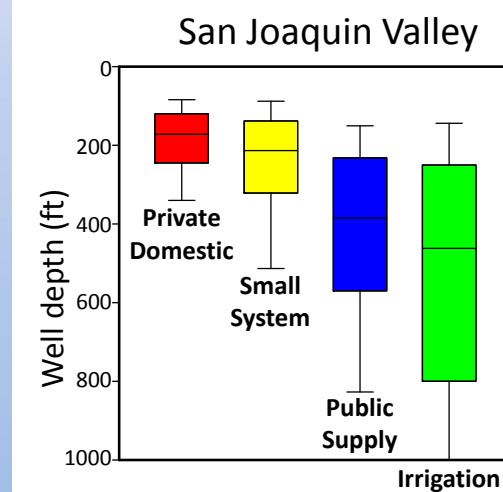
GAMA PBP: Second Phase 2013-2024

- **Shallow Aquifer Assessment**
 - Why assess shallow groundwater quality?
 - Design of a Statewide comprehensive Shallow Aquifer Assessment
- **Assessment of trends in public-supply aquifers**
- **Funding scenarios**



Why Assess Shallow Groundwater? Resource Used by Domestic Wells

- Over 2 million Californians rely on private domestic or small water system wells not regulated by the State – largely unknown water quality
- Domestic and small system wells are shallower than public supply wells



- State Water Board report on “Communities that rely on a contaminated groundwater source for drinking” concluded additional data are needed on shallow aquifers

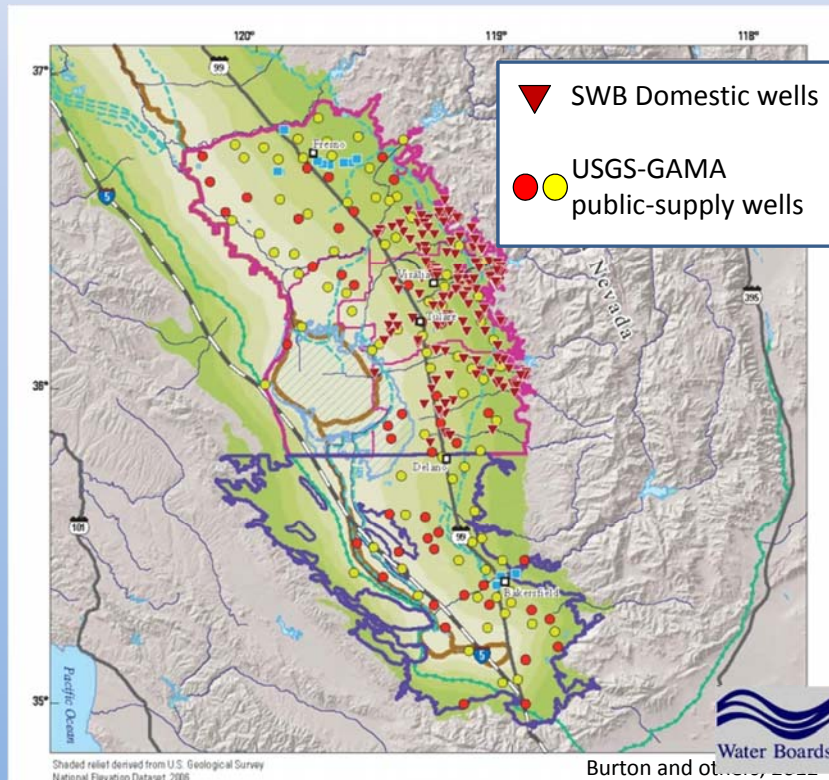


Why Assess Shallow Groundwater? Distribution of Nitrate

- State Water Board report “Recommendations for addressing nitrate in groundwater”: identify areas at greater risk for high nitrate to prioritize assistance and regulatory efforts
- So far, focus on Tulare Basin and Salinas Valley – need a Statewide assessment to show where nitrate is high and where it is not



Example: Tulare Basin



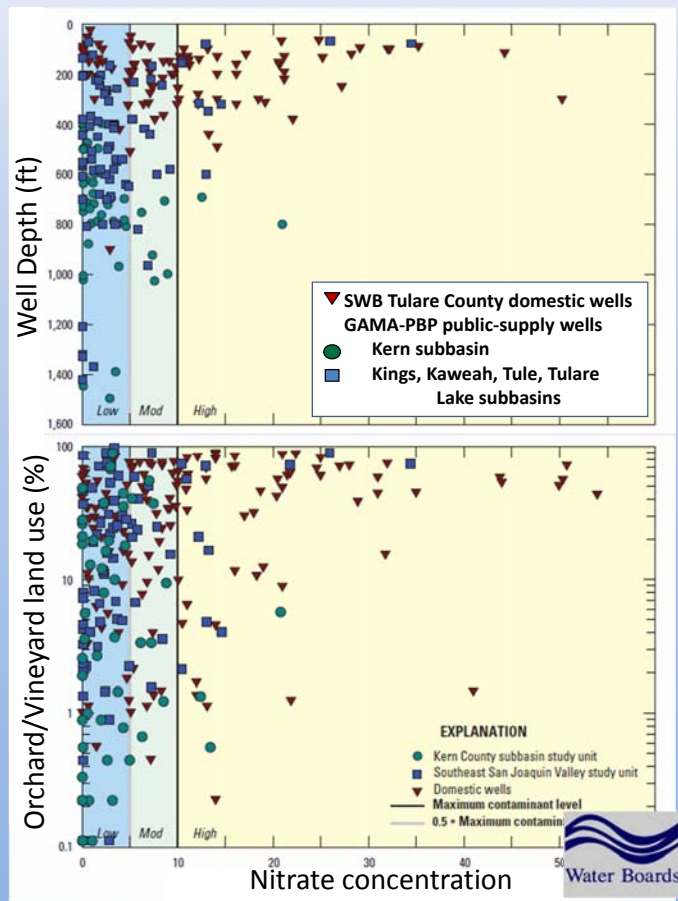
Tulare Basin

Nitrate concentrations correlated with depth and land use

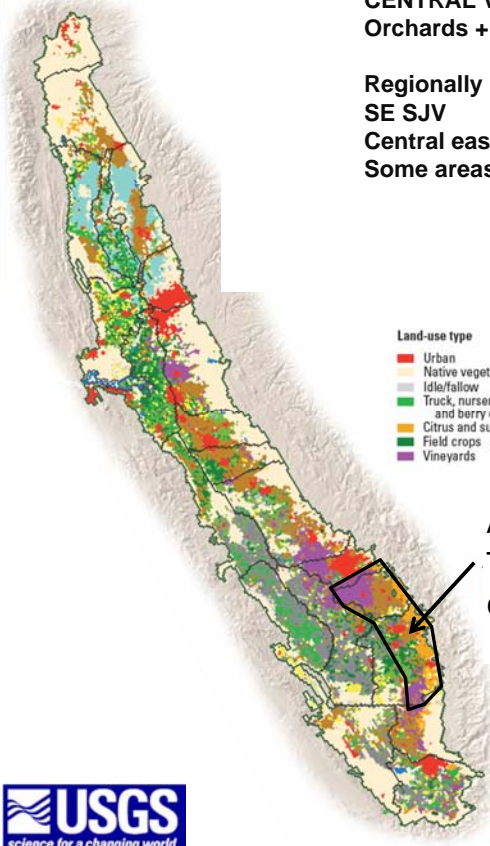
Most of the high nitrate concentrations are in domestic wells



Burton and others, 2012



Land Use 2000



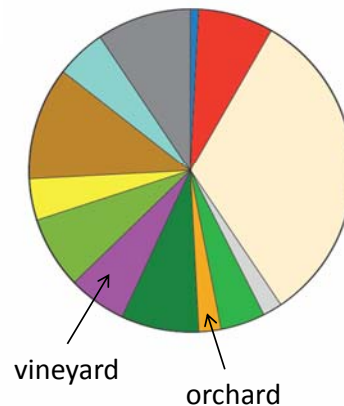
CENTRAL VALLEY
Orchards + Vineyards, ~ 15%

Regionally important:
SE SJV
Central eastside, SJV
Some areas, SacV

- Land-use type
- Urban
 - Native vegetation
 - Idle/fallow
 - Truck, nursery, and berry crops
 - Citrus and subtropical field crops
 - Vineyards
 - Pasture
 - Grain and hay
 - Deciduous fruits and nuts
 - Rice
 - Cotton
 - Water

Area of SWB Tulare County domestic wells

Central Valley Land Use



Faunt and others, 2009



Why Assess Shallow Groundwater? Context for Local-Scale Monitoring Programs

- **Studies of irrigation and engineered recharge commonly focus on first-encounter groundwater – how does the quality of this recharge water compare to regional ambient groundwater quality?**
- **Over what timescales will changes in land use and water use practices change ambient groundwater quality?**



Why Assess Shallow Groundwater? Predict Future Quality of Deeper Groundwater

- **In many areas of California, groundwater is moving downward – to what extent will contaminants in shallow groundwater affect the quality of deeper groundwater?**
- **What anthropogenic and natural processes affect contaminants in shallow groundwater?**



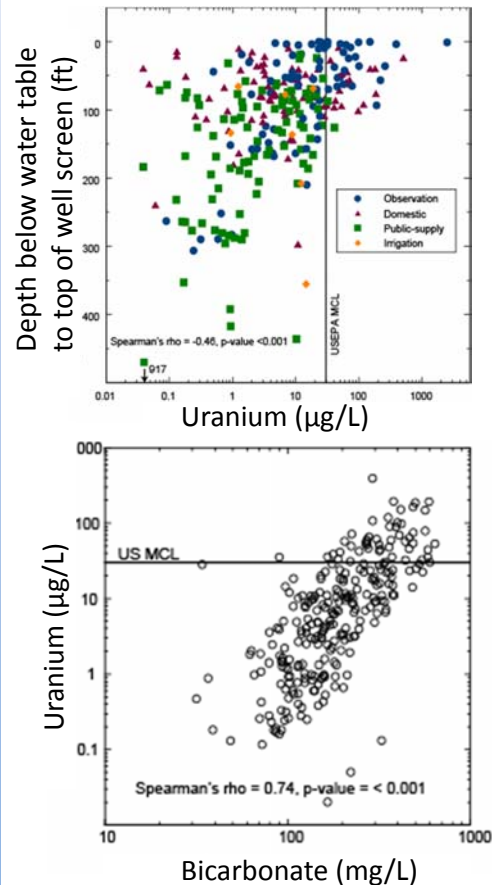
Example: Uranium in the Eastern San Joaquin Valley

High uranium in shallow groundwater due to mobilization of natural uranium from sediments by bicarbonate-rich irrigation return water

Uranium concentrations will continue to increase in depth zone used for public-supply as this recharge water moves downward



Jurgens and others, 2010



Design of a Statewide Comprehensive Shallow Aquifer Assessment

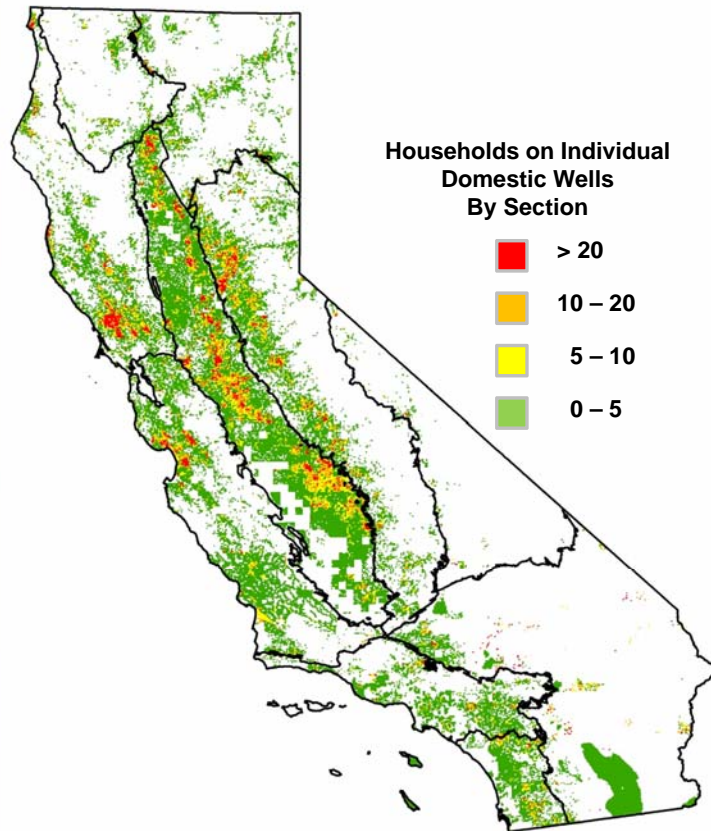
- Prioritization of areas used for domestic supply – analogous to identification of priority basins for original GAMA-PBP
- Implementation – use successful methods from original GAMA-PBP
- Pilot study in three areas using existing GAMA-PBP funds



Prioritization: Where are domestic wells used?

Derived from USGS-
GAMA statistical analysis
of DWR scanned drillers'
logs and 1990 U.S. Census
data

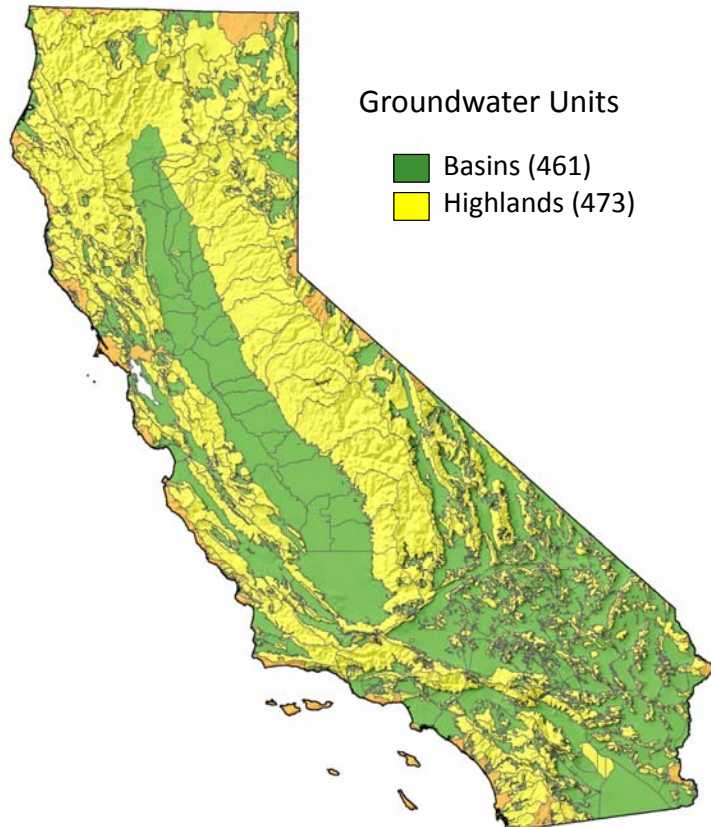
Estimated 466,000
households



Prioritization: Groundwater Units

Basin GWUs correspond to
DWR alluvial groundwater
basins

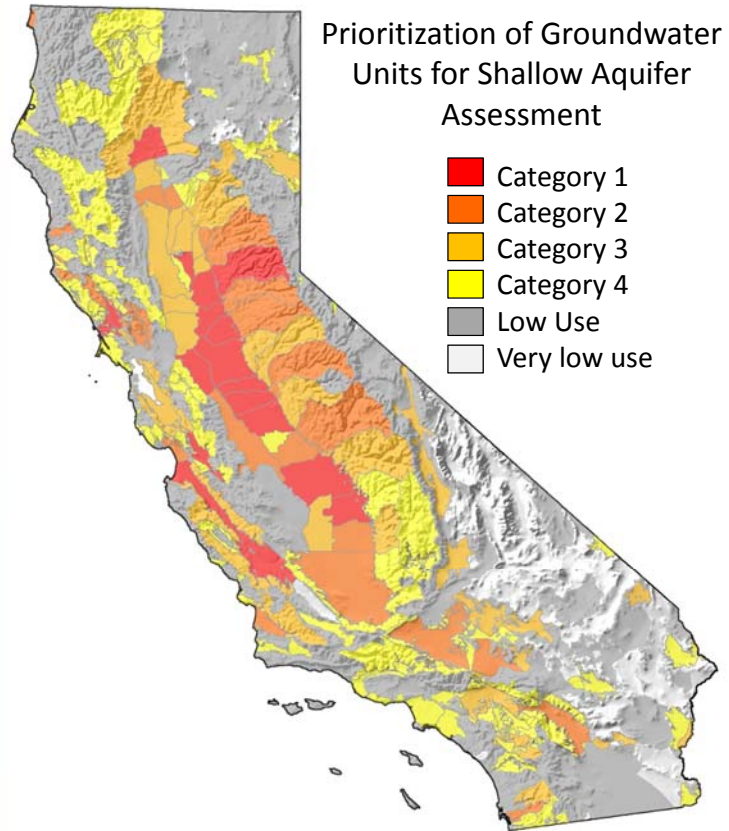
Highland GWUs defined as
areas upgradient of basin
GWUs



Prioritization: Ranking GWUs

Prioritization based on
number and density of
households using
domestic wells

Categories 1-4 cover 90%
of households using
domestic wells statewide



Shallow Aquifer Assessment: Implementation

- **Assess 90% of resource over 10 year period**
 - Sample all Category 1-4 groundwater units
 - Spatially distributed design – use larger grid cells than in original GAMA-PBP for cost savings. Requires 1,000 – 1,200 wells
- **Well selection**
 - Use DWR scanned drillers' logs to identify potential wells
 - Sample shallow aquifer using private domestic wells and small system wells
- **Data collected**
 - Analyze full suite of organic (VOCs and pesticides) and inorganic (major ions, trace elements, nutrients, radioactive constituents)
 - Geochemical and age-dating tracers
 - Compile electronic data (USGS database, county agencies, etc.)



Shallow Aquifer Assessment: Products

- Status of groundwater quality in shallow aquifer
- What are the constituents of concern and where are they found at high and low concentrations?
- Understanding of natural and anthropogenic processes affecting groundwater quality in shallow aquifer
- Comparison of shallow aquifer and deeper public-supply aquifer
- Evaluation of processes affecting fate and transport of contaminants from shallow aquifer to deeper public-supply aquifer



Pilot for Shallow Aquifer Assessment

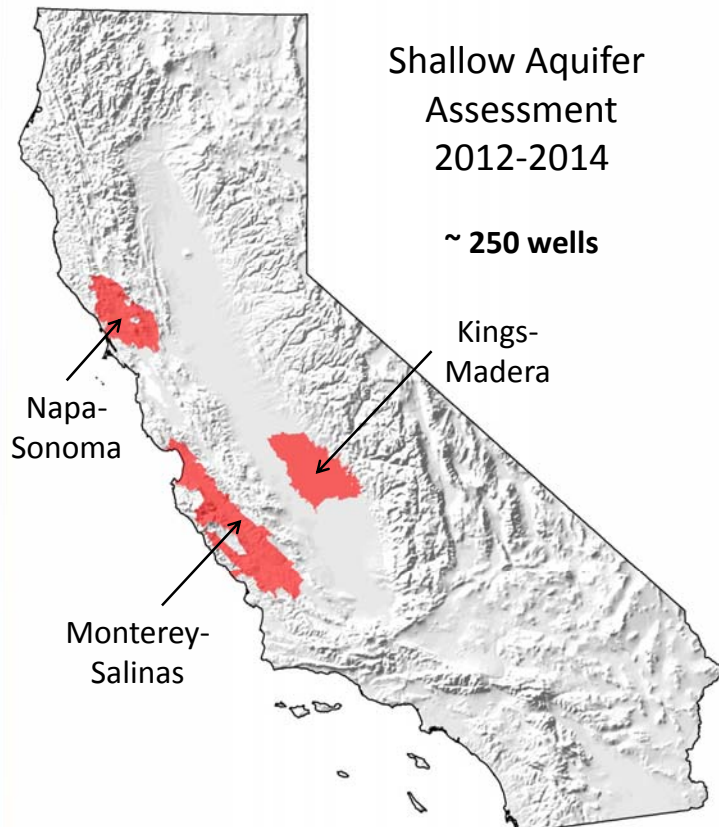
Using existing GAMA-PBP funds

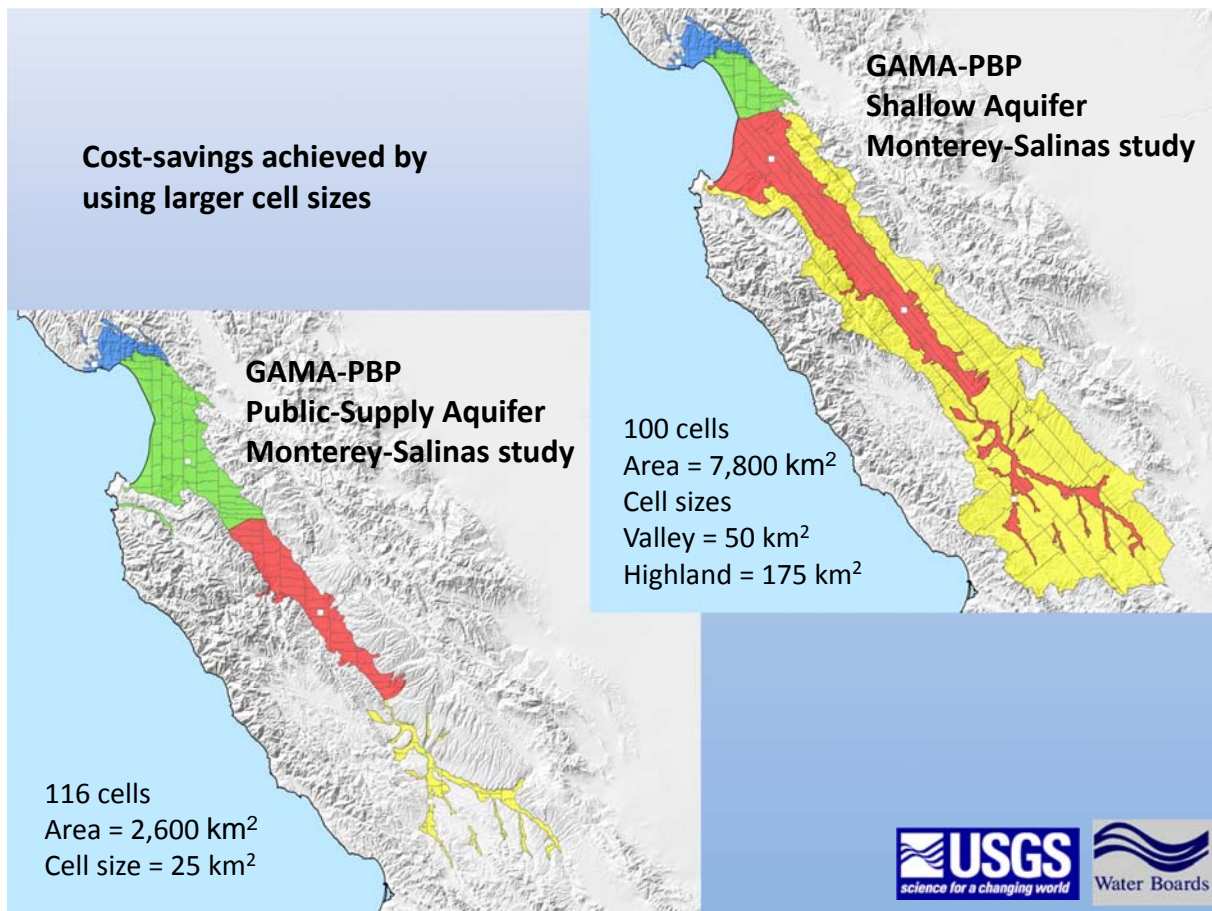
Corresponds to about 20% of the statewide assessment



Shallow Aquifer Assessment 2012-2014

~ 250 wells





GAMA PBP: Second Phase 2013-2024

- **Shallow Aquifer Assessment**
 - Why assess shallow groundwater quality
 - Design of a Statewide comprehensive Shallow Aquifer Assessment
- **Assessment of trends in public-supply aquifers**
- **Funding scenarios**

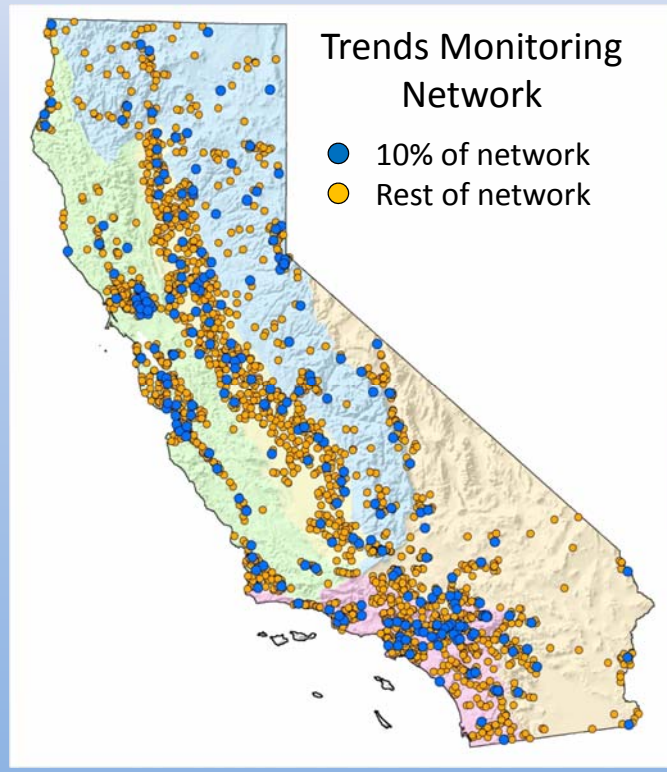


Trends Monitoring: Original GAMA PBP Plan

Sample 10% of network every 3-4 years and full network every 10 years

Costly – requires 2,500 samples over 10 years

Yes, this would closely monitor trends, but is it the best use of resources?



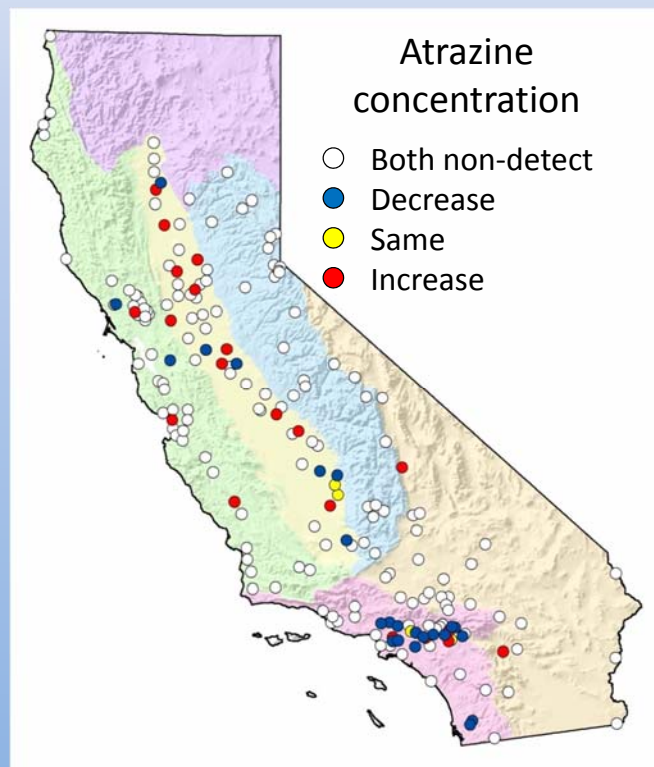
Triennial Trends Preliminary Results

218 wells grouped into 6 regions

Compare initial data to 3-yr data

A few significant changes found:

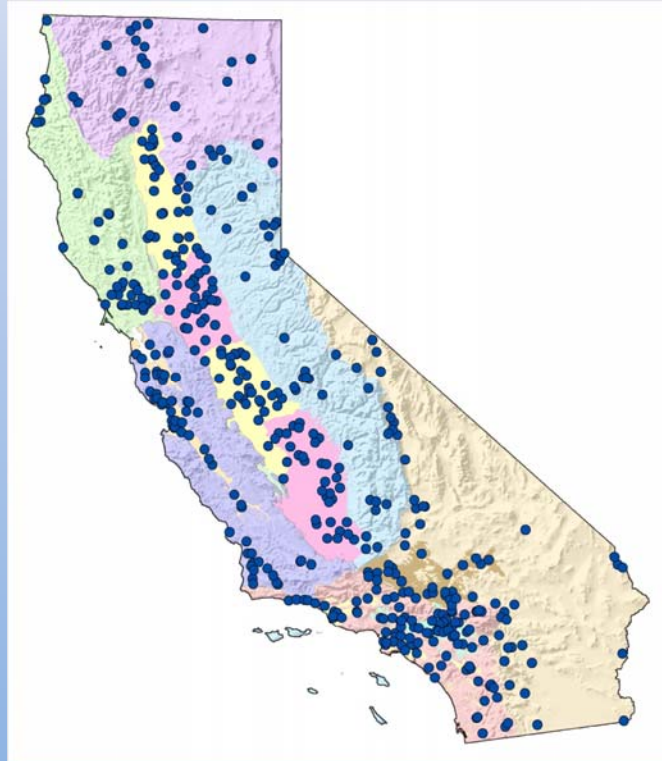
- Atrazine decrease in Southern CA
- Deethylatrazine increase in Central Valley



Alternative Proposal for Trends Monitoring

400 – 500 wells sampled every 10 years

Monitors trends in public-supply aquifers on scale of 14 regions



GAMA PBP: Second Phase 2013-2024

- **Shallow Aquifer Assessment**
 - Why assess shallow groundwater quality
 - Design of a Statewide comprehensive Shallow Aquifer Assessment
- **Assessment of trends in public-supply aquifers**
- **Funding scenarios**



Cost of GAMA Priority Basin Project

- **Original program (2004-2014): \$5M per year (\$50M total)**
 - Nearly all from Prop 50 funds
- **Proposed program (2014-2024)**
 - Shallow Aquifer Assessment: \$2.4M per year (\$24M total)
 - Public-supply Aquifer Trends: \$560K per year (\$5.6M total)
 - Source of funds?
- **Short-term funding**
 - Minimum funding: \$800K per year
 - Source of funds?
- **Without new funds, GAMA PBP sampling will end in 2014**



Questions?

